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HISTORICAL OUTLINE OF THE ELECTRICAL UNITS *

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Scope and Purport. The purpose of this presentation is to trace the outlines of the historical development of electromagnetic units down to the present day, as a branch of the great and important subject of scientific units, and to analyze their existing status as a basis from which an estimate may be made of the direction of their future progress.

Relations of Units to Basic and Applied Science. In basic mathematics—the fundamental science of quantity—units are not of primary importance. The fundamental properties of arithmetic, algebra, geometry, trigonometry, dynamics, etc. are not dependent upon the existence of any particular set of units. A basic proposition in geometry, such, for instance, as the Pythagorean theorem concerning the squares on the sides of a right-angle triangle, would be true in Euclidian geometry for any units of length. From this point of view, basic mathematics is superior to and independent of the science of units. The multiplication table, the binomial theorem, the differential calculus, do not need any particular set or sets of units. To assign some particular unit to an equation in dynamics setting forth a fundamental proposition is to belittle it by the suggestion that it could only be true if that particular unit were used.

In those branches of science which depend upon measurement, however, and especially in applied science, the choice of units of measure becomes important. The mental and material confusion resulting from a multiplicity of arbitrary

* The substance of two lectures before the Electrical Engineering Session of the Summer School for Engineering Teachers of the Society for the Promotion of Engineering Education, Pittsburgh, Pennsylvania, July 9 and 10, 1928.

units led to a search for a system of units as simple, few and nearly universal as possible. That search is still going on. Meanwhile, the study of "unitology," or the branch of science dealing with units, is gaining momentum. The state of development of the units and standards in any branch of applied science is a criterion of that branch's development at the period considered.

Conditions That Should Be Met by a System of Scientific Units. From numerous opinions that have been expressed by specialists in the subject at different times, a list of conditions may be formulated which a system of scientific units should meet:

A. It should be as simple and as comprehensive as possible, capable of being extended in various directions to meet the needs of new scientific branches, international in character, to serve all countries and languages.

B. It should be in the decimal system of numerical relations, and all subsidiaries of any unit should stand in decimal multiple or submultiple relation thereto.

C. There should be one and only one unit in the system for each and every recognized physical quantity. The magnitude of the unit should be that logically pertaining thereto in the system, without regard to practical convenience of size, the need for which should be met through decimal subsidiaries.

D. Each and every recognized unit in the system should have its own individual name, internationally adopted. The decimal subsidiaries of the unit, selected for their convenience of size, should carry the name of the unit with a prefix or suffix to indicate the decimal relationship.

E. The various units of the system should maintain, as far as possible, unitary (one-to-one) relation, without recourse to numerical constants. Thus, the unit of mass divided by the unit of volume should give the unit of density, and again the unit of voltage divided by the unit of resistance should give the unit of current.

F. The system should be used both in science and in everyday affairs. In other words, there should not be one system for the laboratory and another for the market place.

It will be evident that the system or systems of scientific units in general use meet all of the above conditions to a greater or less extent. Their comparative merits reveal themselves rather by the number and degree of exceptions or uncompleted requirements.

Relations with International Metric System. At the present time requirements *A* and *B* can only be met by a system based on the International System of Weights and Measures, the great gift of France to science and international intercourse at the close of the eighteenth century, which is in use among the scientists of all countries as well as among the peoples of most of the countries of the world. The metric system is peculiarly well adapted to form the basis of an international scientific unit system, although a few objections have been raised against it, that are worth a brief examination, as follows:

a. That it is a decimal system, and a duodecimal system would be better.

The duodecimal base 12 has four factors—2, 3, 4, and 6—whereas the decimal base 10 has only two—2 and 5. To secure two more factors it would be necessary to change the arithmetical base in all countries to 12. The number 10 would then mean what is now called twelve, 100 would mean one hundred and forty-four, as we now count, and so on. Besides the present hopelessness of making this change in world arithmetic, the new system of numbers would be harder to learn and operate. There might be a loss rather than a gain in the change.

b. That the international meter is not precisely its designed length of one-ten-millionth of the earth's meridian quadrant, and is therefore only an arbitrary length of no primordial significance.

The standard international meter is admitted to be short of its theoretical value by about 0.2 mm.,* or 1/5000 part. Some error, of course, would necessarily exist, as it is inconceivable that a geodetic measurement of this kind could be carried out to perfection, but the discrepancy is not serious

* Bibliography 70, p. 161.

and can be corrected for when high geodetic precision is required. Moreover the meter is the only yard measure which makes the sea-mile equal to the land-mile (the kilometer equal to one minute of meridian arc) in the decimal system of angular measure, which has already largely displaced * the sexagesimal angular system in France.

c. That the liter is not precisely a cubic decimeter, and is therefore only an arbitrary measure of volume.

The liter is defined as the volume of 1 kilogram of water at 4° C. under a pressure of 76 cm. of mercury, and, according to the best measurements, exceeds the theoretically intended volume of a cubic decimeter in the ratio 1.000,027, or 27 parts in a million,† an error of insignificant magnitude for most practical purposes. In other words, the standard kilogram, designed to be equal to the mass of a cubic decimeter of pure water at 4° C. and 760 mm. of mercury, was executed by the joint international commission in 1799 apparently 27 milligrams overweight;—a remarkably good piece of international metrological work at that date. Moreover, the error might be eradicated, if it were considered internationally to be worth removing, by altering the pressure from 76 cm. to about 118 cm. of mercury in the existing definition of the liter.

Early Electrical Units and Standards. If we take the observation attributed to Thales of Miletus (600 B.C.), that rubbed amber attracted light material particles, as the first recorded experimental fact in electricity, it seems that no record appears of an electric or magnetic unit for more than two thousand years after that event.

Experimenters with frictional electrical machines in the eighteenth century occasionally made crude measurements in arbitrary units, such as angular deflections of torsion balances, but it was not until the beginning of the nineteenth century that rough international electrical units and standards became possible.

* Bibliography 69, pp. 40, 41, 42.

† Bibliography 63, p. B. 16; also 70, p. 385.

The Voltaic Cell the First Practical Electrical-Circuit Unit and Standard. The announcement of the discovery of the voltaic cell * in March 1800 opened the first opportunity of measuring electromotive forces in terms of those produced by voltaic cells of different chemical types. At first this voltaic unit was crude and uncertain, but in 1873 Latimer Clark † published a description of his standard zinc-mercury cell as the outcome of electrochemical researches carried on since 1867. More recently, the Weston zinc-cadmium cell has come to be used as a reliable secondary standard of e.m.f. in terms of the international volt. Some time, however, before the development of these refined voltaic standards, e.m.f.'s employed in telegraphy were estimated in terms of such industrial units as Grove or Daniell cells.

Union of the Magnetic and Electric Branches of Science. The discovery and public announcement by Oersted ‡ of the deflecting action of an electric current upon a suspended magnetic needle called the attention of physicists to the interconnection of magnetism and electricity which, up to that date, had been regarded as separate and independent. Oersted's experiment was repeated by Arago in Paris before the French Academy on September 11, 1820. Professor André Ampère of the École Polytechnique was in the audience and was strongly interested by the demonstration. Repeating and extending the experiments, Ampère was able to announce at the next following meeting of the Academy (September 18), an important generalization of the phenomenon. Ampère's researches § placed electromagnetics on a firm quantitative foundation, although they did not then receive definite unit magnitudes.

The next great step towards the quantification of electric circuit relations was Ohm's publication ‖ in 1827 of the

* Bibliography 1.
† Bibliography 9.
‡ Bibliography 2.
§ Bibliography 3.
‖ Bibliography 4.

law bearing his name. This simple law connecting the e.m.f., resistance and current, in a simple steady-state circuit, has had a great influence on the development of electrical applications.

Absolute System of Magnetic Units. A few years after Oersted's discovery of the magnetic effect of an electric current, galvanoscopes began to appear which gave deflections in arbitrary scale divisions when actuated by steady electric currents. After the dissemination of Ohm's law, rough measurements could be made of the current in simple circuits, using different numbers of cells for adjustable e.m.f. and different lengths of wire for adjustable resistance. Means were not yet available for reducing such measurements to a common basis of comparison. Gauss in Göttingen seems to have been the first to realize how such observations of magnetic phenomena might be reduced to absolute measure in terms of length, mass and time. His celebrated paper * published in 1833 on the strength of the earth's magnetic field reduced to absolute measure showed how the torque exerted on a deflected magnetic needle could be reduced to absolute units. Incidentally, this was among the last papers, and may itself have been the very last, to employ the Latin language, for communications in physics, to the learned societies of the world. Latin had been the principal international learned language of the European world from the days of the Roman Empire to the beginning of the nineteenth century, and no person could pretend, during all that period, to become familiar at first hand with current learning who was unable to read Latin.

W. E. Weber who collaborated with Gauss in Göttingen showed in 1840 how an electric current could be measured in absolute units by its action on the horizontal suspended needle of a "tangent galvanometer," after the horizontal component of the earth's local magnetic field in absolute measure had been determined. From this date until about

* Bibliography 5.

1890 precise measurements † of electric currents were made either with an electro-dynamometer or with some modification of the tangent galvanometer, so that a knowledge of the horizontal intensity of the earth's local magnetic field was of some importance. Electrical laboratories during this period, ordinarily avoided the use of steel in their construction in order to avoid setting up irregularities in the earth's local magnetic field.

Weber further showed in 1851 how e.m.f.'s and resistances might be measured in absolute measure. He measured and calibrated at that date certain coils of wire * deposited at the University of Leipzig having resistances corresponding to what we should now call 2.5, 5, and 10 ohms, respectively. The system of units used by Gauss and Weber in their absolute measurements was the millimeter-milligram-second (mm.-mg.-s.) or M.M.S. system, in direct decimal relation with the international metric system.

Early Demand for Electrical Units from Telegraph Engineering. By the year 1850 electric telegraphy was making good headway in commercial operation. The first Morse telegraph demonstration was in 1837 and the first telegraph line in America was opened for business in 1844 between Washington and Baltimore. The first public telegraph company in England opened for business in 1845, although electric telegraphy had been employed by the Great Western Railway Company as early as 1838. The first successful attempt at submarine telegraphy was in 1850, when a gutta-percha covered wire was laid across the Straits of Dover. The first cable to connect the British Islands with North America was laid in 1858, although it only operated for a few weeks. Permanent transatlantic cable communication was established in 1866. An urgent demand for electrical units, measures and measuring instruments came from the telegraph engineers.

First B.A. Committee Reports. A paper on the need of scientific units for electric communication was presented by

† Bibliography 14, Vol. II, page 322, "Electromagnetic Instruments."

* Bibliography 12.

Messrs. Latimer Clark and Charles Bright to the Manchester meeting of the British Association for the Advancement of Science (generally known briefly as the *B.A.*) in 1861, and a B.A. committee was then formed to report upon "Standards of Electrical Resistance." The members of the committee were among the leading physicists and telegraph engineers of the day. The work of this important committee and of its successors has been epoch-making in the history of electrical units and standards. This committee presented a report almost every year until 1867, when it was dissolved. It recommended the adoption of the meter-gramme-second system of absolute units (M. G. S.). It also issued standard B.A. resistance coils in "ohms" of 10^7 M.G.S. electromagnetic units, and standard "microfarad" condensers, the "farad," after some discussion, being taken as 10^{-7} M.G.S. electromagnetic units. It was first established at the value 10^{-13} M.G.S. (the present microfarad) * but was later changed to 10^{-7} M. G. S. (its present value) in order to preserve the one-to-one sequence of the volt, farad and weber. These standards would still pass as B.A. ohms and microfarads today. The name "weber" was proposed for the practical unit of quantity—our present coulomb—and what we now call an ampere would then have been called a "weber per second." † Actually the "per second" was dropped, and the "weber" did duty ‡ for our present "ampere" until 1881. However, the first B.A. committee did not get further than the ohm and farad during its six years of activity. It proposed the "volt" as the name for the practical unit of e.m.f., defined as 10^8 M.G.S. electromagnetic units, but the committee was unable to deliver voltaic cells of sufficiently definite and reproducible e.m.f. to serve as standards. As thus defined, the Daniell bluestone cell had an e.m.f. of about 1.08 volts, but was quite unreliable as a precise standard. The Clark standard cell of 1873 was the outcome of researches to produce a satisfactory voltaic standard of e.m.f.

* Bibliography 8. Preface.

† Bibliography 8 and 9.

‡ Bibliography 74.

Early Standards of Resistance. The first resistance box, or instrument for inserting or withdrawing definite numbers of resistance units in a circuit, is attributed to Sir Charles Wheatstone in 1840.* His standard resistance unit was one foot of copper wire weighing 100 grains (6.48 gm.).

Dr. Werner Siemens produced, in 1860, the standard Siemens mercury unit, consisting of a column of pure mercury one meter long and of one sq. mm. uniform cross section, at 0° C. The standard consisted of a glass tube carefully calibrated in dimensions into which pure mercury was drawn. Resistance coils of insulated German silver wire were calibrated from such standards. A Siemens mercury unit was nearly one ohm (0.954 B.A. ohm) or 1 B.A. ohm was 1.048 S.U.. In other words, the B.A. ohm corresponded to the resistance of a uniform mercury column 104.8 cm. long and 1 sq. mm. in cross section, at 0° C.

Prior to 1860, resistance boxes had been constructed and used in the telegraph services of Germany (1848), France, England and Switzerland, in units based on either the local mile of those countries (or on the kilometer), for some particular size of telegraph wire of iron or copper.† These local resistance units varied between 9 and 60 B.A. ohms, approximately. They disappeared in the sixties in favor of the Siemens mercury unit, and in the early seventies they were nearly all replaced by the B.A. ohm.

The first B.A. committee report, of 1863,‡ discussed both the foot-grain-second (F.G.S.) system and the meter-gram-second (M.G.S.) system as bases of absolute measures, but clearly leaned towards the latter. In the second B.A. report, of 1864 (p. 345), the meter-gramme-second system appears as definitely adopted. A number of B.A.-ohm coils had been made by Elliott Brothers of London, but these coils were not certified by the committee. A vast amount of preliminary research had first to be made into the mechanical and electrical properties of metals and alloys.

* Bibliography 6 and 8.
† Bibliography 8.
‡ Bibliography 7.

The third report, of 1865, indicates that the alloy adopted for the "B.A.-unit" coils was of platinum-silver (66 per cent silver and 33 per cent platinum), an alloy that had been known and used in the arts for nearly twenty years. Its total increase in resistivity from 0° to 100° C. was given as 3.2 per cent. The form and construction of these B.A. standard coils became standardized at that time and are now familiar.

Up to the end of the first B.A. committee's work in 1867, the terms "ohm," "volt" and "farad" are rarely mentioned, although the terms are found in contemporaneous telegraph-engineering literature. It seems that the urge for these names came from the practitioners, and not from the founders of the system, who used the names "B.A. unit" simply.

Second B.A. Committee Reports. The second B. A. Committee was appointed "for the Selection and Nomenclature of Dynamical and Electrical Units." It brought in its first report * in 1873. This report is an important document in the history of electromagnetic units. It points out that it had up to that time been necessary for a person specifying a magnitude in "absolute" units "to mention the three fundamental units of length, mass and time" relied upon. These might be the M.G.S., C.G.S., M.M.S., or F.G.S. groups. The report recommended that one only of these groups should be forthwith definitely accepted, not merely for electricians, but for all scientists. It proceeded to weigh the advantages of the two principal rival systems, namely the meter-gram-second (M.G.S.) and centimeter-gram-second (C.G.S.) systems. It decided in favor of the C.G.S. system, mainly on the ground that in this system the density of water was substantially unity, whereas in the M.G.S. system the density of water is 10^{-6}. The report says:

> "We think that in the selection of each kind of derived unit, all arbitrary multiplications and divisions by powers of ten, or other factors, must be rigorously avoided, and the whole system of fundamental units of force, work, electrostatic and

* Bibliography 10, and 13.

electromagnetic elements must be fixed at one common level—that level, namely, which is determined by direct derivation from the three fundamental units once for all selected.

"The carrying out of this resolution involves the adoption of some units which are excessively large or excessively small in comparison with the magnitudes which occur in practice; but a remedy for this inconvenience is provided by a method of denoting decimal multiples and submultiples, which has already been extensively adopted, and which we desire to recommend for general use.

* * * *

"Special names, if short and suitable, would, in the opinion of a majority of us, be better than the provisional designations 'C.G.S. unit of . . .' . Several lists of names have already been suggested; and attentive consideration will be given to any other suggestions which we may receive from persons interested in electrical nomenclature.

* * * *

"For the expression of high decimal multiples and submultiples, we recommend the system introduced by Mr. Stoney, a system which has already been extensively employed for electrical purposes. It consists in denoting the exponent of the power of 10, which serves as a multiplier, by an appended cardinal number, if the exponent is positive, and by a prefixed ordinal number if the exponent is negative.

"Thus 10^9 grammes constitute a *gramme-nine;* $1/10^9$ of a gramme constitutes a *ninth-gramme;* the approximate length of a quadrant of one of the earth's meridians is a *meter-seven,* or a *centimeter-nine.*"

The report goes on to recommend for smaller multiples, the well known prefixes *mega, kilo, hecto, deca, deci, centi, milli,* and *micro,* indicating that the prefix *mega* is equivalent to the affix *six,* and the prefix *micro* is equivalent to the prefix *sixth.*

The report therefore recommends that names should be given to the fundamental C.G.S. units, and that in cases where the magnitude of the C.G.S. unit is inconvenient for practical purposes, the derived practical unit should be connected directly with the C.G.S. unit by an appropriate decimal suffix or affix. Thus, if the C.G.S. unit of current strength had been named at that time the ampere, then the practical unit we now call the ampere would be the *deciampere.* Again, if

the C.G.S. unit of resistance had been then named the ohm, then the practical unit we now call the ohm would be the *ohm-nine*, while if the C.G.S. unit of e.m.f. had been then named the volt, then the practical unit we now call the volt would be the *volt-eight*. If this plan had been carried out, a great simplification would have resulted and endless trouble would have been saved, because all the practical units would have remained C.G.S. units, or the necessity for the independent practical volt-ampere-ohm system would have been averted.

The report recommends three new unit names, all in the C.G.S. system: namely, the *dyne* for the C.G.S. unit of force, the *erg* for the C.G.S. unit of work, and the *erg per second* as the C.G.S. unit of power. It defines the horsepower as approximately "7.46 *erg-nines per second.*"

The report states however:

> "The 'ohm' as represented by the original standard coil, is approximately 10^9 C.G.S. units of resistance; the 'volt' is approximately 10^8 C.G.S. units of electromotive force; and the 'farad' is approximately $1/10^9$ of the C.G.S. unit of capacity."

These statements are inconsistent with the recommendation that C.G.S. units should be the fundamental quantities with names, and that the derived units should be decimally related to them through the proper prefixes. It would appear that the report virtually admitted failure in carrying out its recommendation with respect to the already existing practical units—ohm, volt and farad.

This report of 1873 placed the C.G.S. system on the internationally accepted basis of the world's absolute scientific unit system, although its signers were not unanimous as to the centimeter. One of them openly dissented and had his name registered as being opposed to the centimeter. The report formulated, however, the sound, logical principle of one and only one universal scientific absolute system, recommending the C.G.S. system, with names for the C.G.S. units, and prefixial or affixial names for all derived units. In this respect, however, the report came ten years too late. The practitioners had already adopted the ohm for 10^7 M.G.S.

units, or 10^9 C.G.S. units, and in like manner for the volt and farad. They would be unlikely to change the term "ohm," to which they were already accustomed, into the name "ohmnine." The practical volt-ampere-ohm system was launched and under way, originally as a mere appendage to the M.G.S. system, and, after 1873, as a mere appendage to the C.G.S. system, but later it presented itself as an independent scientific system with sovereign rights and privileges.

Birth of the Practical Volt-Ampere-Ohm System. The C.G.S. system supported by the B.A. reports of 1873 and 1874, and also the three practical units and unit-names—volt, ohm and farad—steadily gained favor among scientists and electrical engineers respectively, but no international action concerning them took place until the first "International Congress of Electricians" at Paris, in September, 1881. This congress passed the following resolutions:

> "(1) That the C.G.S. system of electromagnetic units be adopted as the fundamental units.
>
> "(2) That the practical units, the ohm and the volt, preserve their existing definitions, 10^9 and 10^8 C.G.S. units respectively.
>
> "(3) The ohm to be represented by a column of mercury 1 sq. mm. in cross section at the temperature of 0° C.
>
> "(4) That an International Commission be appointed to determine, for practical purposes, by fresh experiments, the length of the mercury column 1 sq. mm. in cross section, at a temperature of 0° C., representing the ohm.
>
> "(5) That the current produced by a volt through an ohm be called an ampere.
>
> "(6) That the quantity of electricity carried by an ampere in one second be called a coulomb.
>
> "(7) That the unit of capacity be called a farad, defined by the condition that a coulomb in a farad raises its potential one volt."

This international agreement established the five units and unit-names in the practical system—ohm, volt, ampere, coulomb, and farad. Perhaps it was not then foreseen, that the subsystem might attain such importance, with time, teaching, and practical use, as to make it assume a dominant rôle to

which the C.G.S. system might eventually become subordinate, thus reversing their original relations. Yet, looking back, this tendency seems to have been inevitable from the outset. The practical units had names, while their C.G.S. parents had none. All practical electrical workers used measuring instruments indicating in practical units. Very few electricians worked with the C.G.S. units in a practical way; so that the practical units gradually became the real entities, and their forbears, the C.G.S. units became their shadows.

The reason for adopting 10^8 C.G.S. units of e.m.f. for the volt was that the e.m.f. of a Daniell copper-zinc bluestone cell became in this way about 1.1 volts, and as early as 1870 a voltaic cell was a common rough standard of e.m.f. among telegraphists.

The reason for selecting 10^9 C.G.S. units of resistance for the ohm, was that the Siemens mercury unit became in this way about 0.95 ohm, and in 1865 the Siemens unit was already a standard of resistance among telegraphists.

The Q.E.S. Practical System. The volt and ohm having been thus fixed, the whole series of corresponding practical units became predicated. Maxwell pointed out * that the practical volt-ohm-ampere series formed an absolute system (Q.E.S.), in which the unit of length was 10^9 cm., or a *quadrant* of the earth, the unit of mass 10^{-11} gm. or an *eleventh-gram*, and the unit of time the mean solar second (the magnetic permeability of free space being taken as unity). The Q.E.S. system has never found favor as a complete scientific system, because the unit of length was so large and the unit of mass so small. Even within the boundaries of the electrical units, inconvenient sizes of derived units became conspicuous. Thus, the unit of current being the ampere, that of current density in the Q.E.S. system became the ampere per square quadrant.

Electrostatic and Electromagnetic Duplicate C.G.S. Subsystems. It has been pointed out by several physicists at different times that measurements of forces between magnets, or between currents, or between magnets and currents involve

* Bibliography 14.

certain * space constants, or properties of the intervening medium. By taking the magnetic and the electrostatic space constants each as unity, the C.G.S. system breaks up into two parallel associated subsystems: namely, the C.G.S. electromagnetic subsystem, and the C.G.S. electrostatic subsystem. Outside of the regions of these subsystems, *i.e.* in the regions of dynamics, heat, chemistry, etc., the C.G.S. system remains single and undivided. Within the subsystem duplicate regions, there are two different units and unit magnitudes for each physical quantity, so that the title C.G.S. unit here becomes ambiguous, in the absence of context or qualification. The numerical ratios between corresponding units in the two subsystems were shown by Maxwell and others to be either v, v^2 or reciprocals of these, where v is approximately 3×10^{10} cm per second, or the velocity of propagation of electromagnetic disturbances in free space. Thus, distinguishing the electrostatic units by the prefix "stat" and the electromagnetic units by the prefix "ab," the approximate value of the statvolt is 3 abvolt-tens, the abampere 3 statampere-tens, and the abcoulomb 3 statcoulomb-tens, while the statohm is nearly 9 abohm-twenties, the stathenry 9 abhenry-twenties, and the abfarad 9 statfarad-twenties. The abjoule and the statjoule are, however, both identical with the erg.

In the discussion of electrostatic phenomena, the mathematical formulas are often simpler in the electrostatic than in the electromagnetic subsystem, while, on the other hand, discussions of electromagnetic phenomena are often simpler when electromagnetic units are employed; so that there is justification for the retention of both subsystems. The electromagnetic units have been on the whole, however, much more generally employed.

Aid to the Introduction of the C.G.S. System. At the time when the C.G.S. system was recommended by the second B.A. committee for international and universal scientific use, its introduction was facilitated by the publication of a little treatise entitled "Illustrations of the C.G.S. System of Units, With Tables of Physical Constants" by Pro-

* Bibliography 17, 25, 35, 52.

fessor J. D. Everett, who was the reporter of the B.A. 1873 committee. This treatise explained the C.G.S. system with numerous examples of formulas and constants. It was first published in 1875, and went through several editions.

It was originally contemplated by the framers of the practical ohm-volt-ampere series of units and standards, that electrical calculations would be carried on in the M.G.S. or C.G.S. system, and the results converted from these into practical units in the final stage. All the theory was to be in, say, C.G.S. units, and all the measurements made in the practical units. At the outset the procedure took place in this way, but as time went on electrical workers became familiar with the volt-ampere-ohm system, and found that they could use it conveniently and rapidly in many directions without going back to first principles in C.G.S. At the present time only new and unexplored fields of electrical theory call for analysis in the C.G.S. system, or fields contacting with mechanics, chemistry, or other branches of science. In most electrical applications the workers are able to dispense with C.G.S. units altogether, and so avoid the mental inconvenience of transferring from one system to the other.

The Legal Ohm. Prior to the year 1880, it had been pointed out by Rayleigh, Rowland and others, that the B. A. standard ohm was distinctly below its theoretical value of 10^9 C.G.S. units. The Paris Congress of 1881, as already mentioned, charged an international commission with the task of determining the revised length of the square-millimeter mercury column that should be taken at 0° C. as representing the ohm of 10^9 C.G.S. units. This international commission published its findings in 1884. It recommended taking 106.0 cm, the B. A. standard ohm corresponding approximately to 104.8 cm. The commission considered that the most reliable estimate of the length corresponding to the true ohm would be more nearly 106.3 cm, but decided to recommend only the nearest exact centimeter (106) until more numerous good measurements would enable the correct number of millimeters to be added. The name of-

fered for the new standard ohm of 106.0 cm was the "legal ohm." It has since been known by that name. Legal-ohm resistance boxes began to replace B.A.-ohm boxes about the year 1885. Some telegraph services, however, decided to retain their B.A. standards until the next approximation should be decided upon. The then newly developing electric light industry adopted the legal ohm as a general principle.

By the year 1885 there were thus three recognized types of ohm: (1) The absolute ohm of 10^9 C.G.S. units, which, strictly speaking, was an unrealizable goal, towards which science aimed at eventually arriving, (2) The B.A. standard ohm of 104.8 cm of specified mercury column, (3) The legal ohm of 106.0 cm.

Measures of Electromotive Force and Current Strength. Although the standards and measurement of resistance and capacitance were in a fairly satisfactory condition, for practical purposes, by 1865, and voltaic cells furnished rough standards of e.m.f., yet no satisfactory degree of precision was attained in the standards and measurements of e.m.f. and current until the production of the Clark standard zinc-mercury cell in 1873. The e.m.f. of this element was originally reported to be 1.457 volts* at 15° C., but later determinations reduced this to 1.434 volts on the basis of the international ohm and a slightly modified technique of cell construction. The establishment of the standard B.A. ohm and of the standard B.A. volt through the Clark cell enabled the ampere (then called† the *weber*), to be measured to a certain degree of precision after 1873. Practically, however, the ampere was in most cases measured to a lesser degree of precision with the aid of the tangent galvanometer set up in localities where the earth's horizontal magnetic field had been determined in absolute measure. The fashion became fairly general, between 1875 and 1890, to build special "galvanometer houses," without iron or steel, specially to contain tangent galvanometers for the more precise measurement of electric

* Bibliography 9.

† Bibliography 74.

currents. The advent of electric lighting circuits in the early eighties drew attention to the need for both stationary and portable voltmeters and ammeters. The terms *voltmeter* and *ammeter* also date from the early eighties. They were first called "potential galvanometers" * and "ampere-galvanometers," later "amperemeters," respectively.

The electrodynamometer, introduced originally by Weber, was used as a stationary instrument for current absolute measure by the first B.A. committee, and by Latimer Clark in 1872 for evaluating the e.m.f. of his standard cell. A complete series of electrodynamometer instruments, voltmeters, ammeters and wattmeters, was brought out by Lord Kelvin in 1888 as stationary devices. Instruments of the D'Arsonval type, both stationary and portable, began to be used in the later eighties. Conspicuous among them were the Weston instruments, which first appeared in 1888. For the highest precision of current measurement, however, the voltameter still continues to be used for the deposition of silver at a steady measured rate.

Second International Congress of Electricians at Paris in 1889. The International Electrical Congress of 1889 adopted three more units and unit names in the practical system; namely, the *joule* as the practical unit of energy, equal to 10^7 C.G.S. units, the *watt* as the unit of power, equal to 10^7 C.G.S. units and the *quadrant* as the unit of self-inductance, equal to 10^9 C.G.S. units. The Congress defined the joule and watt, however, not only in terms of the C.G.S. units, but also in terms of the practical system. The Congress also discussed magnetic units in the practical system, recommending the "maxwell" as the name of a practical unit of magnetic flux equal to 10^8 C.G.S. magnetic units and the "weber" as the name of a practical unit of magnetic flux density, equal to 10^8 C.G.S. magnetic units. The Congress did not, however, take any action on these suggested magnetic units.

Magnetic-Circuit Units Brought under Discussion. The rapid development of dynamo machines during the eighties led to a demand among electrical engineers for magnetic

* Bibliography 16.

units with names attached for use in the analysis and description of magnetic circuits. The first international evidence of this need manifested itself at the second international electrical congress at Paris, as above mentioned.

In 1891, the American Institute of Electrical Engineers appointed a committee on "Units and Standards," with special reference to the study of magnetic-circuit units. The committee reported in favor of adopting units of magnetomotive force, magnetic flux, magnetic flux density, and magnetic reluctance, all in the practical volt-ampere-ohm system. It was recommended that names should be sought for these units, internationally, but no names were suggested in the report, which was made in June, 1891. No action was taken by the A. I. E. E. at that time.

The subject of magnetic units was discussed at the third International Electrical Congress, held at Frankfort, in September 1891. The names of "Gauss" and "Weber" were recommended, in the practical system, for the units of field intensity and magnetic flux, respectively, but no action was taken.

Fourth International Electrical Congress, Held at Chicago in 1893. The Chicago Congress of 1893 was notable in the history of electrical units. It was able to formulate specifications for the standard ohm to a precision of one-tenth of one per cent, or one per mil, owing to the steady international accumulation of measurements of preëxisting resistance standards in absolute measure. Its decisions formed the basis of much legislation in all parts of the world, in reference to electrical units and standards. Prior to the Chicago Congress, changes in the international electrical units might have been possible, because not many countries had enacted laws concerning electrical standards. Soon after the Chicago Congress, however, material changes in electrical units could only be introduced with great difficulty, since these units and their standards were entered on the statute books of many countries.

The Chicago Congress addressed its resolutions from the Chamber of Delegates to the various governments represented, recommending them to "formally adopt as legal units of

electrical measure," the following units: the ohm, ampere, volt, coulomb, farad, joule; watt and henry, all in the practical system. These (except for the *henry*, which was a new name for the *quadrant* of the preceding Paris congress), were replications of the units and unit names already adopted internationally, but differed slightly therefrom in magnitude, owing to the changed specification adopted for the new standard ohm. The Chicago-congress series was therefore called for distinctiveness, the *International Series of Units*, and its individual members, the *international ohm, international volt*, etc., as follow:

"*Ohm.* As a unit of resistance, the *international ohm*, which is based upon the ohm equal to 10^9 units of resistance in the C.G.S. system of electromagnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14.4521 grammes in mass, of a constant cross-sectional area and of the length of 106.3 cm.

"*Ampere.* As a unit of current, the *international ampere*, which is one-tenth of the unit of current of the C.G.S. system of electromagnetic units, and which is represented sufficiently well for practical use by the unvarying current which, when passed through a solution of nitrate of silver in water, and in accordance with accompanying specifications, deposits silver at the rate of 0.001,118 of a gramme per second.

"*Volt.* As a unit of electromotive force, the *international volt*, which is the electromotive force that, steadily applied to a conductor whose resistance is 1 international ohm, will produce a current of 1 international ampere, and which is represented sufficiently well for practical use by 1000/1434 of the electromotive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C., and prepared in the manner described in the accompanying specifications.

"*Coulomb.* As a unit of quantity, the *international coulomb* which is the quantity of electricity transferred by a current of 1 international ampere in one second.

"*Farad.* As a unit of capacity, the *international farad*, which is the capacity of a condenser charged to a potential of 1 international volt by 1 international coulomb of electricity.

"*Joule.* As a unit of work, the *joule*, which is equal to 10^7 units of work in the C.G.S. system, and which is represented sufficiently well for practical use by the energy expended in one second by an international ampere in an international ohm.

> "*Watt.* As a unit of power, the *watt*, which is equal to 10^7 units of power in the C.G.S. system, and which is represented sufficiently well for practical use by work done at the rate of 1 joule per second.
>
> "*Henry.* As the unit of induction, the *henry*, which is the induction in a circuit when the electromotive force induced in this circuit is 1 international volt, while the inducing current varies at the rate of 1 ampere per second."

It will be seen that the ohm, ampere, joule and watt were defined on the basis of the corresponding units in the C.G.S. system, with standards according to specifications for the ohm and ampere, but with reference to the practical system, for the joule and watt. In the case of the volt, the unit is defined with reference to the practical system, while its standard is defined with reference to a specified voltaic cell. The coulomb, farad and henry are defined in terms of the practical system only.

Specifications were appended to the resolutions, in regard to the construction and use of the silver voltameter, and specifications for the construction of the Clark cell were relegated to an international committee.

In regard to magnetic-circuit units, it was resolved that the C.G.S. system be commended, and that for the present no names be given to these units.

It is to be remembered that magnetic observatories, observing and recording the earth's magnetic field in various countries since 1850, had continued to make their measurements in absolute units, and since 1875 in C.G.S. units. This was regarded by magneticians as a reason for retaining magnetic units and standards in the C.G.S. system. Many objections appeared in electrical literature, between the years 1890 and 1894, to the adoption of magnetic-circuit units in the practical system. On the other hand, electrical engineers working with the design, analysis and construction of dynamo-electric machines and magnetic circuits were insistent upon units and unit names for the essential elements of such circuits.

Heaviside Rational System of Units. Heaviside drew attention in 1882 to the fact that both the C.G.S. electrical

units and their congeners the practical electrical units had been somewhat "irrationally" chosen. Thus, in place of the definition that a unit magnetic pole exerted unit force (1 dyne) upon a similar and equal pole situated at unit distance (1 cm.) in free space, he advocated the definition that a unit pole should be such as was acted upon by unit force when situated in a magnetic field of unit intensity. The "rational" system of units which he recommended, differed from the existing C.G.S. units, not in dimensions of length, mass and time, but in numerical ratios of 4π, $\sqrt{4\pi}$ or their reciprocals. These ratios involved changes in most of the electrical units and standards that would be definite, but very inconvenient to effect. There was much force in the arguments on behalf of the Heaviside rationalzed units and formulas. If these arguments had been presented to the first B.A. committee, at the date of formation of the C.G.S. electric system, they might have prevailed. Once the existing C.G.S. system became adopted, however, and especially after the ohm-volt-ampere system derived therefrom had entered into national legislative enactments, it became very difficult to make such a change. For example, a standard resistance of 1 B.A. ohm would become, under the Heaviside plan, a standard of 0.079,577··· rational * B.A. ohms. All standards, and most instruments, in electrical service would have needed recalibration. No international electrical congress since 1893, has been willing to discuss the question of rationalizing the units, and only a few physicists have preferred to use rational instead of the existing C.G.S. units, in their theoretical discussions, for the sake of a greater degree of simplicity in the formulas.

Although the completely rationalized Heaviside system of electrical units has never been seriously considered internationally, owing to the gravity and extent of the changes it would involve, yet various suggestions have been made to rationalize the units, standards and formulas of certain portions of the system, especially the magnetic-circuit units and the electrostatic "circuit" units. Thus, in both the C.G.S. and practical existing systems, the systematic value of m.m.f.

* Bibliography 22.

is 4π times the current-turns, whereas the rationalized value would be the current-turns simply, thereby suppressing the factor 4π. Again, in both the C.G.S. and practical existing systems, the capacitance of an air condenser formed by plane parallel plates, separated by a distance d, is $1/4\pi d$ per unit of surface, whereas the rationalized value would be $1/d$ simply, again suppressing the factor 4π. A system rationalized to this extent, without affecting the units and standards of voltage, current, power, etc. may be called, for present purposes, a *subrationalized system*. Several subrationalized systems have been proposed * at different times.

Fifth International Electric Congress of 1900 at Paris. In view of the recommendation of the Chicago Congress, already mentioned, for retaining the working magnetic units in the C.G.S. system, the committee of Units and Standards of the A. I. E. E. reported in May 1900 in favor of fixing the working units of the magnetic circuit with names, in the C.G.S. system, and of considering their rationalization. The names suggested were: the "gilbert" for m.m.f., the "oersted" for reluctance, the "maxwell" for flux, and the "gauss" for flux density. The A. I. E. E. adopted the report and directed its delegates to recommend accordingly at the forthcoming Paris Congress.

At the Paris Congress of August 1900, there was considerable difference of opinion. It was generally agreed that the working magnetic-circuit units should be retained in the C.G.S. system, but there was considerable opposition to giving them names. The Congress finally printed in its report the adoption of two names: † namely the "gauss" for the C.G.S. unit of field intensity, and the "maxwell" for the C.G.S. unit of magnetic flux.

No formal change has taken place in the international magnetic-unit situation since the 1900 Paris Congress. There has, however, been some divergence of use since that date. In some countries the *gauss* has been used exclusively for field intensity H. In others it has been used exclusively for

* Bibliography 18, 20, 21, 23, 26.

† Bibliography 24.

flux density B, while many writers have used it for both H and B indiscriminately. Moreover, the matter has been further complicated by the fact that some physicists have in recent years contended that the physical quantities H and B are identical in dimensions, so that magnetic permeability μ is no more than a pure numeric. In the United States it has been customary to use the *gilbert-per-cm.* for H, the *gauss* for B, the *maxwell* for flux ϕ and the oersted for reluctance ν, all in the C.G.S. system.

Among students and observers of terrestial magnetism, and especially in the records of terrestial magnetic observatories, the unit "gamma," with the symbol γ, has been employed during the past thirty years. The present writer is indebted to the Office of the Director of the Terrestrial Magnetism Department of the Carnegie Institution at Washington for the information that the term appears as early as 1896, in "Terrestial Magnetism and Atmospheric Electricity," 1896, Vol. I, page 57, footnote 2, where M. Eschenhagen, says (translation):

"As a brief and convenient symbol of the measured (magnetic) force, use might be made of a unit for the fifth decimal of the electromagnetic unit, represented by a letter, such as the Greek γ suggestive of the name Gauss; so that 0.000,01 C.G.S. $=\gamma$, which might likewise indicate the approximate limit of precision in the measurement of the earth's magnetic field."

The reference shows that if the C.G.S. unit of magnetic field intensity is expressed as 1 gauss, then a centi-milli-gauss, would be represented as 1γ. Terrestial magnetic records are commonly expressed in C. G. S. units to the fifth decimal place, or to the order of precision of the gamma.

The symbol Γ (capital gamma) was also used at one time to represent the C.G.S. unit of magnetic field intensity H; so that $1\gamma = 0.000,01\Gamma$, but the Γ seems to have dropped out of use.

Sixth International Electrical Congress at St. Louis. The international electrical congress of 1904 took no action on units, either in the Chamber of Government Delegates or in

the various sections, but voted to invoke an international commission, representing the various governments, to consider questions relating to electrical units and standards upon which international agreement was desired. It also voted to take steps "to secure the cooperation of the technical societies of the world, by the appointment of a representative commission to consider the question of the standardization of the nomenclature and ratings of electrical apparatus and machinery."

It is significant that no electrical congress has taken action on electrical units or standards since that of Paris in 1900. Indeed, considering the extent to which electrical units and standards have been incorporated in national legislations since the Congress of 1893, there has been a marked restriction in the possibilities open for action by international electrical congresses. There has remained, however, a considerable field for international effort in bringing the electrical standards of the different countries into agreement and in raising the precision of such standards, but this was not a task in which international congresses could materially assist. It was a task devolving upon the various governmental departments legally charged with the maintenance of electrical standards.

Both the above resolutions came into subsequent effect. The first led to a succession of international conferences on electrical units, attended by government representatives of the different national laboratories. The second led, under the leadership of Col. R. E. Crompton, to the establishment of the International Electrotechnical Commission (I. E. C.).

International Conference on Electrical Units at Berlin in 1905. The first conference of representatives of the national laboratories was invited by the Charlottenburg Reichsanstalt to meet in Berlin, in October, 1905.

The Chicago Congress Chamber of Delegates had adopted resolutions, as quoted, which paved the way for national legislation on electrical units and standards, but there were certain outstanding questions still to be settled in order that the volt, ohm, farad and henry standards arrived at in the different countries might conform to the basic absolute measures

and to each other within a desired degree of precision. In particular the Chicago resolutions specified standards for the international ohm and volt, besides specifying a voltameter for evaluating the international ampere. But these three unit standards, being connected by Ohm's law, only two of them can be regarded as primary standards. The ohm has always been regarded as the first primary standard, and the standard international ohm was defined at Chicago in terms of a mercurial column. There were differences of opinion as to whether the second primary standard should be the standard volt obtained from a standard cell or the standard ampere as determined from a specified voltameter.

A week before the Berlin conference assembled a meeting was held in London of the British Electrical Standards Committee, at which it was unanimously agreed "That two units should be defined independently and that these two should be the unit of resistance and the unit of current." This resolution was communicated to the Berlin Conference.

The U. S. Bureau of Standards presented certain advance proposals to the Berlin Conference and among them the following:

> "(2) We suggest that the three units be defined as in memorandum B, only two (the ohm and the volt) being independent. If further research shall demonstrate that the silver coulometer is more reproducible and more reliable for precision measurements than the cadmium cell, we shall be willing to reconsider this choice."

The Berlin (Charlottenburg) Conference held five sessions and reached a series of conclusions, among them the following:

> "(1) That only two electrical units shall be chosen as fundamental units.
>
> "(2) The International ohm defined by the resistance of a column of mercury, and the International Ampere defined by the deposition of silver are to be taken as the fundamental electrical units.
>
> "(3) The International Volt is that electromotive force which produces an electric current of one International Ampere in a conductor whose resistance is one International Ohm.
>
> "The Weston Cadmium Cell shall be adopted as the Standard Cell."

Specifications were recommended in detail for the construction of the mercury ohm standards and of the Weston Standard Cells.

The International Conference on Electrical Units and Standards at London in 1908. The London Conference held in October, 1908, was attended by official delegates from twenty-four countries. Its principal purpose was to decide upon mutually satisfactory definitions and specifications for the principal electrical standards. The international electrical units were defined as at preceding conferences in terms of the C.G.S. units, but their standards, for legislative purposes, were recommended to be constructed according to specifications. The fundamental standards were to be the mercury-column ohm and the silver-voltameter ampere. The International Ohm standard was specified substantially as in the Chicago-Congress resolutions, but with additional specifications. The International Ampere was defined as depositing silver at the rate of 0.001,118,00 gm. per second. The two final zeros in this numerical specification were adopted, after some discussion, to imply that comparisons might be carried to 1 part in 100,000. The Weston normal cell e.m.f. was taken as a subsidiary standard with the provisional value 1.0184 international volts at 20° C. The question as to whether the ampere or the volt was to be the fundamental standard after the ohm was settled in favor of the ampere by a vote of nineteen countries against four.

An international technical committee was appointed to draw up improved specifications for the silver voltameter and to decide upon the value of the e.m.f. assignable to the Weston normal cell.

International Technical Committee Meeting at Washington in 1910. A technical committee composed of representatives from the national laboratories of France, Germany, Great Britain, and the U. S. A. met at the Bureau of Standards in Washington in the spring of 1910 to make comparisons of standards of resistance, current and voltage. As a result of their tests, this Committee recommended that the

e.m.f. of the Weston normal cell be taken as 1.0183 volts at 20° C. The International Committee to which the recommendation was addressed, adopted this value in October, 1910, and the various national laboratories adopted it in January, 1911.

The International Electrotechnical Commission. As already mentioned, the I. E. C. came into existence in conformity with a recommendation of the St. Louis Congress of 1904. It first convened in London in 1906 for organization. Since that time it has held eighteen meetings, all told, in various cities of Europe and America. There have also been numerous smaller committee meetings. The I. E. C. is participated in by twenty countries. Its work is divided among thirteen technical advisory committees which report to the main body from time to time. A principal task of the I. E. C. has been the international determination of the ratings of electrical machinery and of the tests by which such ratings are determined. Its proceedings have dealt but little with the creation or precise maintenance of electrical units or standards with a few exceptions that may be here pointed out.

Seventh International Electrical Congress at Turin. At the Turin meeting of the I. E. C. and associated International Electrical Congress in 1911 a short list of algebraic symbols was adopted for the designation of certain electric and magnetic quantities. The standard direction of alternating-current phase rotation was also agreed upon, so that the impedance of a coil was fixed as $R + jX$ ohms, and not $R - jX$. Moreover, the symbology of Ohm's law, which previously had been different in different countries, was standardized internationally. For example, Ohm's law had previously been symbolized in English-speaking countries under the form $C = E/R$, which form is still retained historically on the emblem of the National Electric Light Association. The form internationally agreed upon was, and since has been, $I = E/R$.

At the Bellagio meeting of the I. E. C. in 1927 an "Expert's Paper" was presented relating to terms, definitions,

units and symbols affecting electric power generation,* and also a communication from the Italian Committee proposing a unit for magnetic flux in the practical volt-ampere-ohm system and the selection of some name for the same. The Italian Committee's proposal was referred † to an international subcommittee for consideration. The matter is still in sub-committee at this date (July 1928).

International Electrical Congress proposed for 1915. It had been proposed to hold an International Electrical Congress (the eighth) at San Francisco in 1915 in conjunction with a meeting of the I. E. C., but the outbreak of the World War annulled the project. The Turin Congress of 1911 was therefore the last to date.

The International Conference of Weights and Measures. The International General Conference of Weights and Measures is an organization participated in by many countries for the maintenance of world standards of weights and measures, at the International Bureau of Weights and Measures in Sèvres, on the outskirts of Paris. The international standard meter and the international standard kilogram are deposited there. Working copies of both are maintained in the Pavillon de Breteuil laboratory at this Sèvres Bureau. The Bureau certifies copies of the standard meter and kilogram. The buildings of the Bureau rest upon a piece of international land, removed by French legislative enactment from the surrounding French territory. Hitherto, only standards of length and mass, with appropriate adjunct apparatus, have been maintained at the Sèvres International Bureau. If no such bureau existed, new copies of these standards would presumably have to be furnished by some national laboratory, whereas all countries are enabled to keep in touch with the Sèvres Bureau in order to maintain their length and mass standards with the needed precision.

In recent years it has been proposed to extend the functions of the International Bureau of Weights and Measures

* Bibliography 72.

† Bibliography 71.

to include electrical and other standards. A resolution to that general effect was voted in 1921 by the General Conference of Weights and Measures, in session at that time in Sèvres. Certain amendments to the International Convention were executed at that date to permit of extending the functions of the Bureau. An international advisory committee was created in 1927 to formulate plans for carrying out the extension. The plans have not yet been reported, but it is supposed that they will develop some system whereby certified copies of electrical standards can be obtained on application to the Sèvres Bureau. At the present time a new copy of an ohm standard, for example, could presumably only be obtained with high-grade precision by application to some national laboratory. Whereas, however, copies of the international meter have been produced at Sèvres with a "probable error" not exceeding 0.2μ (0.2 micron, or millionth of a meter) * and copies of the international kilogram with a "probable error" not exceeding 0.005 milligram,* the international standard ohm and volt cannot as yet be produced or maintained with any such precision.

Precision of Electrical Standards. In order conveniently to express numerical degrees of precision in standards, the following terminology may be permitted:

Order		
2d.	A precision of 1 part in 100	may be called a precision of 1 per cent.
3d.	A precision of 1 part in 1,000	may be called a precision of 1 per *mil.*
4th.	A precision of 1 part in 10,000	may be called a precision of 1 per *myriad.*†
5th.	A precision of 1 part in 100,000	may be called a precision of 1 per *lakh.*‡
6th.	A precision of 1 part in 1,000,000	maybe called a precision of 1 per *meg.*

* Bibliography 27.

† Greek *myria* ten thousand.

‡ From the Sanscrit *laksha*—one hundred thousand—much used in the orient in relation to currency, as "a lakh of rupees."

The first B.A. Committee, after great labor, was able to produce the B.A. standard ohm which fell short of the absolute ohm by about one per cent. Nevertheless, this was a great achievement in 1865, and it filled temporarily the practical needs of that time with reasonable satisfaction. Once a group of B.A. ohm standards had been made up, they were found to maintain their assigned values over a term of years within a precision of, say, 1 per myriad * and individual comparisons between them could be made at any one time to an apparent precision of at least 1 per lakh. These three precisions of production, maintenance and intercomparison are of much individual and mutual importance in the history and development of electrical units, and they all tend to increase as time goes on, although at differing rates. A high precision in producing a standard such as the standard ohm, in reference to the absolute unit, would be of little value if it could not be preserved in a standard of a like degree of precision in maintenance.

At the date of the Chicago Congress, it was generally agreed that the production precision of the international ohm standard had risen to about one per mil and the maintenance precision, over a term of say ten years, was at least 1 per myriad. It was also generally agreed that the production precision of the silver-voltameter technique for producing the international ampere was about one per myriad, but there was some difference of opinion as to the ampere's precision of maintenance in standardized ammeters. These precisions for the fundamental standards have continued to be regarded as satisfactory for most practical needs up to the present time. The general tendency of practical applications is, however, to call for increasing available precision in working standards as time goes on. For scientific purposes, however, these above mentioned precisions were relatively low.

Recent Estimates of the Precision of Electrical Units and Standards. An interesting communication to the A. I. E. E. has recently emanated from the Bureau of Standards relative

* Bibliography 12.

to the present status of the international electric units.* It appears that on the basis of the estimates established for the two fundamental units in 1910, the international ohm and henry are in excess of the corresponding absolute units by about one half per mil (1.000,52),—corresponding to a mercury ohm of 106.245 cm.—the international volt and maxwell are also in excess of their absolute units by nearly the same amount (1.000,43), the international joule and watt are also in excess by one third of one per mil (1.000,34), while the international ampere, coulomb and gilbert are short of the corresponding absolute units by one per myriad (0.999,91).

For many practical purposes, the above estimated discrepancies between the international unit standards and the absolute units are negligible at the present time, but in special cases, where high precision is aimed at, they might have to be taken into account. Moreover, judging from the increase in demand for precision that electrical applications have shown in the last fifty years, the existing discrepancies may become serious in a not far distant future. There has been some difference of opinion on the matter. Some have contended that just as there are certain small errors, definitely established, between the theoretical values of the international meter and kilogram and their standard international prototypes at Sèvres, so the international practical units might be maintained indefinitely through accepted standards, despite the admitted discrepancies between them and their theoretical absolute values. It should be pointed out, however, that the meter and kilogram are independent fundamental units which may be accepted at their standardized values without disturbing the actual dimensions of the globe with which they are theoretically connected, but the practical volt-ampere-ohm system of units are derived units, dependent upon the international meter and kilogram. Errors in the establishment of the practical-unit standards, through lack of production precision, may at any time lead to unlooked for errors in physical measurements that include electrical processes. If we are to retain a single comprehensive international system of units and measures,

* Bibliography 67.

there can be only one volt, ohm and ampere, even if they are not yet producible with all desired accuracy. To set up a divergent international system, outside the pale of readjustment or correction, would be virtually to set up a plurality of meters and kilograms, that, in a certain sense, would be rivals of those deposited in the International Bureau at Sèvres. It is therefore to be hoped that the international electrical standards will not become stereotyped. As the precisions of production and maintenance increase, readjustments can be made in them towards their respective absolute values by international agreement at intervals not so short as to create confusion nor so long as to give a sensible jolt to electrical applications, when introduced.

In any event, it is a matter for satisfaction that since 1865 the precision of production of the ohm has advanced say from one per cent to one per myriad; its precision of maintenance over a ten-year period from perhaps one per mil to one per myriad; and its precision of intercomparison among favorable groups from say one per lakh to one per meg. Similar comparisons might be drawn for the other units. A gain of one order of precision in these directions involves an immense aggregate amount of labor and research.

Present Status of the System or Systems of Electromagnetic Units. At the present time (1928) the status of the electromagnetic system of units is partly satisfactory and partly unsatisfactory. It is satisfactory in being decimal, metric and universal. The rapid strides that applied electricity has made, from the international point of view, must be accredited, at least in part, to these fortunate conditions. On the other hand, it is unsatisfactory because the systems are incoherent and incomplete. The fundamental C.G.S. system is coherent and complete (except for the duplication of units in the electric and magnetic subsystems), but the practical electrical system of units and measures is drifting away from the fundamental C.G.S. system. The practical volt-ampere-ohm system is incomplete, because it breaks down occasionally when carried over the borderland of other branches of science.

As an example, we may take the case of a telephone receiver operated by an alternating current of steady rms. amplitude $I = 2$ milliamperes, at constant frequency, and producing in a plane diaphragm of the piston type a steady rms. vibration velocity $v = 5$ cm per second, against a total mechanic resistance r, including acoustic resistance. If the "motional" resistance of the receiver is $R' = 100$ ohms, then equating input and output we have the known relation:

$$I^2R' = v^2r \qquad \text{power units} \quad (1)$$

In the C.G.S. system the equation is easily solved, since $I = 2 \times 10^{-4}$ abampere, $R' = 10^{11}$ abohms, $v = 5$ kines and $r = 160$ mechanic abohms, so that we obtain 4×10^3 or 4,000 abwatts, as both the electric and mechanic power of the system. If the mechanic resistance on the diaphragm were entirely acoustic, 4,000 abwatts of sound would be produced by the instrument.

If we use the practical system, considered as a Q.E.S. system, then $I = 2 \times 10^{-3}$ ampere, and $R = 100$ ohms. The input is evidently 4×10^{-4} watts, the rms. velocity being 5 cm. per sec. is 5×10^{-9} quadrants per second and r enters in unnamed mechanical units that may be called 1.6×10^{13} mechanic ohms. The power on both sides of the equation then becomes 4×10^{-4} watts. The mechanic ohm is 10^{-11} dynes per kine, or mechanic abohms, so that 160 mechanic abohms are represented by 1.6×10^{13} mechanic ohms. In this case the extension of the practical system into dynamics involves using a very large unit of velocity and a very small unit of mechanic resistance. As yet, none has had the courage to sponsor the mechanical units of the practical system, considered as a Q.E.S. system, for christening and adoption. In such a case, at present, the worker is driven into the C.G.S. system for his conceptions and equations. As a result, the practical system is more or less restricted to the purely electric field, as distinguished from being a comprehensive scientific system. The ohm, volt and ampere are nevertheless entrenched in the laws of a number of countries, so that there is practically very

little hope of replacing them by the corresponding C.G.S. units.

Recent Suggestions for Changes in the International Electrical System. Two types of proposal have been made to change the existing system of practical units since 1882, when Heaviside pointed out defects in the logic of selecting the fundamental definitions. As has already been mentioned, one type of proposal has been the subrationalization of the practical system, since the complete rationalization, suggested by Heaviside, did not meet with favor. Proposals to subrationalize the C.G.S. magnetic system were made by Perry in 1891, Baily in 1895, and Fessenden in 1900. None of these proposals has yet been adopted.

The second type of proposal involved changes in the relations of the practical system to the absolute system. There have been four: (1) the Fleming proposal of 1900, (2) the Giorgi proposal of 1901, (3) the Dellinger-Bennett proposals of 1916, and (4) the French proposal of 1913 and 1919.

(1) The Fleming proposal, in brief, was to rationalize the magnetic circuit by taking the 4π factor out of m.m.f. and inserting it in reluctivity and permeability, at the same time altering the value of the ohm from 10^9 to 10^8 abohms, thus bringing the new resulting ampere and coulomb into identity with the abampere and abcoulomb, respectively. By this plan, the practical system would be virtually converted into a megameter—eighth-gram—second system. The decimal ratios of the units in this system to those in the C.G.S. system would ordinarily be 10^8 or 10^{-8}, instead of more numerous powers of ten. The new practical electrical system would be simplified, but it would be out of touch with other branches of science, such as dynamics, equally with the present practical system.

(2) The Giorgi proposal * of 1901 deserves careful examination, because it offers, perhaps, the best hope yet raised for converting the practical system into a complete and comprehensive scientific system. It proposes to change the base of the practical system from the Q.E.S. to the M.K.S.Ω. (meter-

* Bibliography 25 to 35.

kilogram-second-ohm) system. That is, it adopts the meter and kilogram from the metric system as fundamental units together with the second and the ohm. The second is the mean solar second that all the absolute systems have adopted and the ohm is the international ohm, presumably not stereotyped at 106.3 cm. of mercury column, but capable of being readjusted into closer agreement with the absolute ohm by international convention. By this means, all of the units of the international practical system become inherent components of the new absolute system.

By the further adoption of suitably chosen numerical values for the specific magnetic permeability and electric inductivity of free space, the M.K.S.Ω. system becomes subrationalized in both the magnetic and electrostatic circuits. Moreover, the duplication of the system into two subsystems for these two circuits disappears, so that there is one and only one unit for each electrostatic or magnetic quantity. The unit of m.m.f. thus becomes the ampere-turn without the present 4π factor, and the factor 4π drops out of the formula for finding the capacitance of a plane parallel-plate condenser. This simplification is of course somewhat offset by the necessary insertion of the space constants μ_0 and k_0 in such problems.

In the ordinary use of the M.K.S.Ω. system, the practical units retain their customary relations to one another, but gradients and densities have to be modified to meet the change from the cm. to the meter, if confusion is to be avoided. Thus the systematic unit of potential gradient is the volt per meter, and that of current density is amperes per square meter.

In dealing with the magnetic circuit, we use meters for the dimensions and introduce the space reluctivity $\nu_0 = 10^7/4\pi$ to find the space reluctance before applying the specific permeability μ of the core. Thus, we may consider a magnetic toroid of permeability $\mu = 1000$, one meter long, and 1000 sq. cm. in cross sectional area, excited by 1000 ampere-turns. We may find the magnetic flux and flux-density in both the C.G.S. and in the M.K.S.Ω. systems.

Quantity	C.G.S.	M.K.S.Ω.
Length, L	100 cm. $= 10^2$	1 m.
Sectional Area, S	1000 sq. cm. $= 10^3$	0.1 sq. m. $= 10^{-1}$
Space reluctivity, ν_0	1	$10^7/4\pi$
Space reluctance, $R_0 = \frac{L\nu_0}{S}$	$10^2/10^3 = 10^{-1}$ oersted	$\frac{1}{10^{-1}} \times \frac{10^7}{4\pi} = \frac{10^8}{4\pi}$
Permeability, μ	1000 $= 10^3$	1000 $= 10^3$
Reluctance, $R = \frac{R_0}{\mu}$	$\frac{10^{-1}}{10^3} = 10^{-4}$ oersted	$\frac{10^8}{4\pi \times 10^3} = \frac{10^5}{4\pi}$
Current-Turns, NI	100 $= 10^2$ abampere-turns	1000 $= 10^3$ ampere-turns
Magnetomotive Force, F	$4\pi NI = 4\pi \cdot 10^2$ gilberts	10^3 ampere-turns
Mag. Intensity, $H = F/L$	$4\pi \cdot 10^2/10^2 = 4\pi$ gilb/cm.	$10^3/1 = 10^3$ amp-turns/m.
Magnetic Flux, $\phi = \frac{F}{R}$	$\frac{4\pi \cdot 10^2}{10^{-4}} = 4\pi \times 10^6$ $= 0.1257 \times 10^8$ maxwells	$10^3 \Big/ \left(\frac{10^5}{4\pi}\right) = 4\pi \times 10^{-2}$ $= 0.1257$ P.U.F.
Flux Density, $B = \frac{\phi}{S} = \mu H$	$\frac{4\pi \times 10^6}{10^3} = 4\pi \times 10^3$ gauss	$\frac{4\pi \times 10^{-2}}{10^{-1}} = 4\pi \times 10^{-1}$ $\frac{\text{P.U.F.}}{\text{sq. m.}}$

Here the magnetic flux ϕ comes out 0.1257×10^8 maxwells in the C.G.S. system and 0.1257 P.U.F. in the M.K.S.Ω. system, if we take the name P.U.F. provisionally, for the Practical Unit of Flux. The final name, of course, would have to be determined by international agreement.

Again, we may compute in both systems the capacitance of a plane parellel-plate condenser, the active area of each plate being 1 square meter, the separation being 0.5 cm., with a dielectric of specific inductivity $k = 5$. The C.G.S. formula is $C = Sk/4\pi d$ statfarads. The formula in the M.G.S.Ω. system is $C = Sk_0k/d$ farads.

Quantity	C.G.S.	M.K.S.Ω.
Active area, S	10^4 sq. cm.	1 sq. m.
Separation, d	0.5 cm.	0.005 m.
Space inductivity, k_0	1	8.84×10^{-12} farad/m.
Specific inductivity, k	5	5
Capacitance, C	$\frac{Sk}{4\pi d} = \frac{10^4 \times 5}{4\pi \times 0.5} = \frac{10^5}{4\pi}$ $= 0.796 \times 10^4$ statfarad $= 0.884 \times 10^{-9}$ farad	$\frac{Sk_0k}{d} = \frac{1 \times 8.84 \times 10^{-12} \times 5}{0.005}$ farad $= 8.84 \times 10^{-9}$ farad $= 0.884 \times 10^{-9}$ farad

The value of k_0 is $(10^7/4\pi) \times 1/v^2$, where v is the velocity of propagation of electromagnetic disturbances in free space. Taking v at the approximate value of 3×10^8 meters per second, or $v^2 = 9 \times 10^{16}$, k_0 becomes $1/(3.6\pi \times 10^{10})$ or* 8.84×10^{-12}. It will be seen that the expression of capacitance in this case is simpler and more direct in the M.K.S.Ω. system than in the C.G.S. system.

Equation (1), (p. 262), may be dealt with in the M.K.S.Ω. system by noting that the velocity v is 0.05 m./sec., or v^2 is 25×10^{-4}. The unit of mechanic resistance, say 1 *mechanic ohm*, is 1 *eff* per (m./sec.), or 10^3 C.G.S. mechanic abohms, so that 160 of the latter are 0.16 mechanic ohm. Hence the output v^2r is $25 \times 0.16 \times 10^{-4}$ or 4×10^{-4} watts.

The accompanying table of 42 physical quantities gives their names and numerical values in both the C.G.S. and M.K.S.Ω. systems. Column II gives the symbol for the quantities, Column III the names in the C.G.S. system and Column IV, the corresponding names in the M.K.S.Ω. system. In addition to the "P.U.F.," one unit name has had to be improvised for the purposes of comparative presentation, namely No. 10, the name for force F, which is marked as "eff" in the M.K.S.Ω. system. An *eff* has 10^5 dynes, or is approximately the weight of 100 grams.

* Bibliography 35, 36.

COMPARATIVE TABLE OF C.G.S., M.K.S.Ω AND M.T.S. UNITS

No.	I	II	III	IV	V	VI	VII	VIII
	Quantity	Symbol	C.G.S.	M.K.S.Ω.	C.G.S.U. in the M.K.S.Ω.U.	M.K.S.Ω.U. in the C.G.S.U.	M.T.S.	C.G.S.U. in the M.T.S.U.
	Mechanic							
1	Length	L	cm.	m.	10^2	10^{-2}	m.	10^2
2	Area	S	cm.^{2}	m.^{2}	10^4	10^{-4}	m.^{2}	10^4
3	Volume	V	cm.^{3}	m.^{3}	10^6	10^{-6}	m.^{3}	10^6
4	Time	T	sec.	sec.	1	1	sec.	1
5	Frequency	f	cy. p. s.	cy. p. s.	1	1	cy. p. s.	1
6	Mass	M	gm.	kg.	10^3	10^{-3}	ton	10^6
7	Density	d	gm./cm.^{3}	kg./m.^{3}	10^{-3}	10^3	ton/m.^{3}	10^6
8	Velocity	v	cm./sec.	m./sec.	10^2	10^{-2}	m./sec.	1
9	Acceleration	a	cm./sec.^{2}	m./sec.^{2}	10^2	10^{-2}	m./sec.^{2}	10^2
10	Force	F	dyne	"eff."	10^5	10^{-5}	sthène	10^5
11	Pressure	P	barye	"eff."/m.^{2}	10^5	10^{-5}	pièze	10^5
12	Torque	τ	dyne ⊥cm.	"eff." ⊥m.	10	10^{-1}	sthène ⊥m.	10^4
13	Moment of Inertia	J	gm. cm.^{2}	kg. m.^{2}	10^7	10^{-7}	ton m.^{2}	10^{10}
	Energetic				10^7	10^{-7}		10^{10}
14	Work or Energy	W	erg	joule	10^7	10^{-7}	kilojoule	10^{10}
15	Power or Activity	P	erg/sec.	watt	10^7	10^{-7}	kilowatt	10^{10}
	Thermal							
16	Heat	H	gm. cal.	kg. cal.	10^3	10^{-3}	thermie or ton cal.	10^6
17	Temperature	θ	Deg. C. or Abs.	Deg. C. or Abs.	1	1	Deg. C. or Abs.	1
	Luminous							
18	Luminous flux	ψ	lumen	lumen	1	1	lumen	1

COMPARATIVE TABLE OF C.G.S., M.K.S.Ω AND M.T.S. UNITS—*Continued*

No.	I	II	III	IV	V	VI	VII	VIII
	Quantity	Symbol	C.G.S.	M.K.S.Ω.	C.G.S.U. in the M.K.S.Ω.U.	M.K.S.Ω.U. in the C.G.S.U.	M.T.S.	C.G.S.U. in the M.T.S.U.
19	Illumination	E	phot	lux	10^{-4}	10^{4}	lux	10^{-4}
20	Intensity	I	candle	candle	1	1	candle	1
21	Brightness	b	candle/cm.^{2}	candle/m.^{2}	10^{-4}	10^{4}	candle/m.^{2}	10^{-4}
22	Focal power		cm.$^{-1}$	diopter	10^{-2}	10^{2}	diopter	10^{-2}
	Electric							
23	E.M.F.	E	abvolt	volt	10^{8}	10^{-8}	10^{-2} volt	10^{6}
24	Elec. field	e	abvolt/cm.	volt/m.	10^{6}	10^{-6}		10^{4}
25	Resistance	R	abohm	ohm	10^{9}	10^{-9}	10^{-7} ohm	10^{2}
26	Resistivity	ρ	abohm cm.	ohm m.	10^{11}	10^{-11}		10^{4}
27	Conductance	G	abmho	mho	10^{-9}	10^{9}	10^{7} mho	10^{-2}
28	Conductivity	γ	abmho/cm.	mho/m.	10^{-11}	10^{11}		10^{-4}
29	El. Quantity	Q	abcoulomb	coulomb	10^{-1}	10	10^{6} coulomb	10^{4}
30	El. Displacement	D	abcoulomb/cm.^{2}	coulomb/m.^{2}	10^{-5}	10^{5}		1
31	Capacitance	C	abfarad	farad	10^{-9}	10^{9}	10^{7} farad	10^{-2}
32	Inductivity	k_0		farad/m.	$3.6\pi \cdot 10^{10}$	$(3.6\pi \cdot 10^{10})^{-1}$		
33	Current	I	abampere	ampere	10^{-1}	10	10^{6} ampere	10^{4}
	Magnetic							
34	M.M.F.	F	gilbert	ampere turn	$4\pi/10$	$10/4\pi$		
35	Mag. field	H	gilbert/cm.	amp. turn/m.	$4\pi/10^{3}$	$10^{3}/4\pi$		
36	Reluctance	R	oersted	1/henry	$4\pi/10^{9}$	$10^{9}/4\pi$		
37	Reluctivity	ν_0	oersted cm.	m./henry	$4\pi/10^{7}$	$10^{7}/4\pi$		
38	Permeability	μ_0	1/oersted cm.	henry/m.	$10^{7}/4\pi$	$4\pi/10^{7}$		
39	Mag. Flux	ϕ	maxwell	P.U.F.	10^{8}	10^{-8}		
40	Flux density	B	gauss	P.U.F./m.^{2}	10^{4}	10^{-4}		
41	Inductance	L	abhenry	henry	10^{9}	10^{-9}		
42	Magnetization	J	gauss	P.U.F./m.^{2}	$10^{4}/4\pi$	$4\pi 10^{-4}$		

The M.K.S.Ω. system of Giorgi has been commented upon favorably by Ascoli* and a number of physicists in Italy, Emde† in Germany, Dellinger‡ and G. A. Campbell§ in America. It offers the advantage of making the practical electrical units fundamental elements of a comprehensive scientific absolute system, if internationally accepted. The basis of the proposed system is at least as much electromagnetic as mechanical or dynamical. Fifty years ago objections might have been raised against any absolute system that was not based squarely on dynamics, but as a consequence of those doctrines of relativity which have received general acceptance in recent years, electromagnetics have assumed a primary rôle in modern scientific philosophy, and dynamics a secondary rôle.

The difficulties in the way of the M.K.S.Ω. system are mainly due to its heterodoxy and novelty. If it were adopted, it would displace and supplant the existing C.G.S. system, which is the orthodox leading system of units today, all over the scientific world, in all branches of science, taken collectively. The consent of the scientific world would be necessary for the change, either explicitly, by formal agreement among the various scientific societies, or implicitly, by the publication of a sufficient number of papers in the M.K.S.Ω. system in the various countries to justify the transfer. But little can be done with the M.K.S.Ω. system until it is better known. This system, in order to gain favor, needs such a treatise of formulas and examples in M.K.S.Ω. units, as Everett's treatise offered for the introduction of the C.G.S. system fifty years ago. It would seem that no other barriers than strangeness and unfamiliarity prevent the use of the system. In a certain limited sense, the regular use of the existing practical international system may be regarded as a use of part of the M.K.S.Ω. system. The magnetic-circuit units, of course, would have to be transferred from the C.G.S. to the practical system.

* Bibliography 30, 35, 52.
† Bibliography 33.
‡ Bibliography 56.
§ Bibliography 65.

(3) The International System * is virtually an ohm-ampere-cm.-second system, comprising the international electrical system of practical units, in association with the centimeter as unit of length and the mean solar second as unit of time. Here, as in the M.K.S.Ω. system, the practical electrical units are pillars of the structure. Densities and gradients are taken with reference to the familiar centimeter, such as the ampere per sq. cm. and volts per cm. The magnetic units would preferably be subrationalized, but they would remain as in the C.G.S. system, all but the ampere-turn for m.m.f. and the ampere-turn per cm. for magnetic field intensity H. The unit of mass, however, comes out as 10^7 grams or ten metric tons, and the unit of force 10^7 dynes, or roughly equal to the weight of 10 kg. In view of these awkward values, Dellinger has regarded the International System as applicable only in the electric and magnetic fields of service, and as not adapted to becoming a comprehensive scientific system.*

Prof. Edward Bennett has already used the International System in Publications.†

(4) The last two columns (VII and VIII) of the Table refer to the French System which was proposed in 1913 ‡ and legalized in France by a law and decree of 1919. It is known as the M.T.S. system (meter-ton-second), being based on the international meter, the metric ton of 1000 kg. and the mean solar second. It has the advantages that the sizes of its units are better adapted to the needs of mechanical engineering and of industry, than those of the C.G.S. system, and that the density of water (the ton per cubic meter) is logically retained at unity, as in the C.G.S. system, whereas in the M.K.S.Ω. system, unit density is the kilogram per cubic meter, or 0.001 that of water. In the "International System," the unit of density would be 10 tons per cc. or 10^7 that of water. Unfortunately, the electric and magnetic units come out in the French M.T.S. system different from those of either the practical international system or the C.G.S. system. Conse-

* Bibliography 56.
† Bibliography 59, 60, 66, 68.
‡ Bibliography 63, 69, 70.

quently, it would seem that the French system will be limited to certain branches of science, such as mechanics and dynamics, not including the electric and magnetic units whose system is connected with the M.T.S. system through various decimal or subdecimal links. In other words, it does not seem possible for the M.T.S. system to become a universal, comprehensive, scientific system, in which every physical quantity has a definite systematic place, including the legalized practical electrical units.

Present Prospects for Developments in Electromagnetic Units. It is outside of the province of a historical outline to hazard any guess as to what may happen to the electromagnetic units in the future. It is, nevertheless, permissible to indicate the existing open avenues over which advances may possibly take place, assuming that new and epoch-making discoveries in unitology do not intervene to deflect the forces hitherto at work. The goal to be hoped for is a single, universal, comprehensive, scientific system of units for theory, practice, and international development in all scientific branches, everywhere. The only avenue in sight for reaching this goal seems to be through the M.K.S.Ω. system.

The present situation may, of course, persist for a long period, *i.e.* the C.G.S. system may persist, as the orthodox general scientific system including the magnetic-circuit system, but with the practical electrical system outside and connected by multifold decimal links, electrical workers employing the practical system for the great bulk of their work.

In the mean time, we should not remain supine spectators, waiting for the future to develop. There is no scientific worker who is not brought closely under the influence of complexities in electrical units. Every student and teacher of basic and applied physics is closely concerned in the matter, and the Society for the Promotion of Engineering Education is intimately concerned. Granting, as every scientist will probably grant, that the electromagnetic units must continue to be based upon the international meter and kilogram, the question is whether the existing cumbersome duality between the C.G.S. system in the general field, and the practical system

in the electrical field, should better be allowed to continue indefinitely, or whether efforts should be made to adopt a unified single-track system. If so, what is the best course to take? To be successful, the answer must be sought in international terms. Such changes, confined to a single country, would be likely to create confusion instead of simplicity.

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PROGRAM

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

THIRTY-SIXTH ANNUAL MEETING AT THE

UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL, N. C.,

JUNE 26–28, 1928

Officers for the 1928 meeting.—R. L. Sackett, President; C. E. Magnusson, Vice-President; T. E. French, Vice-President; W. O. Wiley, Treasurer; F. L. Bishop, Secretary, University of Pittsburgh, Penna.

TUESDAY, JUNE 26, 1928

10:00 A.M. Conference on Drawing, 300 Phillips Hall, Thos. E. French, *Chairman.*

Subject: Descriptive Geometry.

Meeting of the Council, 319 Phillips Hall.

2:00 P.M. Opening Session. Gerrard Hall.

R. L. Sackett, President, presiding.

Address of Welcome. Harry W. Chase, President, University of North Carolina.

Response. R. L. Sackett, President of the Society.

A Productive Industrial Plant on College Premises, Herbert Schofield, Principal, Loughborough College, England.

Review of the Report of the Board of Investigation and Coordination as Related to the Engineering School at the University of North Carolina, G. M. Braune, Dean.

A Practical Step Toward Improving Methods of Teaching. H. P. Hammond, Associate Director of Investigations.

Discussion:

E. R. Maurer, University of Wisconsin.

LeRoy Tucker, Clemson College.

T. F. Hickerson, University of North Carolina.
W. J. Risley, Colorado School of Mines.
Reports of Cimmittees:
Civil Engineering, A. H. Fuller, *Chairman.*
Industrial Engineering. J. W. Hallock, *Chairman.*
Relation of Engineering Colleges with Railroads. S. W. Dudley, *Chairman.*
Standardization of Technical Nomenclature. John T. Faig, *Chairman.*
Report of the Treasurer, W. O. Wiley.
Report of the Secretary, F. L. Bishop.

3:30 P.M. Conference of Teachers of Electrical Engineering, Paul Cloke, *Chairman.*
Conference of Teachers of English, Sada A. Harbarger, *Chairman.*
Subject: English as a Developmental Experience.
Conference of Teachers of Mechanics, J. E. Boyd, *Chairman.*
How Much Dynamics Should Be Included in the Course in Engineering Mechanics? N. C. Riggs, Carnegie Institute of Technology.
The Difficulties of the Embryo Teacher of Mechanics and How They Might Be Removed, E. W. Rettger, Cornell University, C. L. Walker, Cornell University.

5:00 P.M. Visit of inspection to Duke University, Durham, N. C.

7:00 P.M. Informal Supper, guests of Duke University.

WEDNESDAY, JUNE 27, 1928

9:00 A.M. Second Session, Gerrard Hall.
R. L. Sackett, President, presiding.
Placement Examinations. Clair V. Mann, Missouri School of Mines.
Discussion: T. M. Focke, Case School of Applied Science. Eugene L. Grant, Montana State College.
Developments in Sanitary Engineering at the University

of North Carolina, Thorndike Saville and H. G. Baity.

College Experience in Its Relation to Achievement in Industry, R. I. Rees, American Telephone and Telegraph Company.

Report of the Board of Investigation and Coordination. Charles F. Scott, *Chairman.*

W. E. Wickenden, Director of Investigations.

Discussion.

12:00 M. Luncheon, Carolina Inn, Guests of University.

2:00 P.M. Meeting of the Institutional Division, 206 Phillips Hall.

C. E. Magnusson, Vice-President of the Society, *Chairman.*

Functions and Organizations of Institutional Division, W. E. Wickenden.

Discussion:

H. J. Hughes, Harvard University.

A. A. Potter, Purdue University.

C. F. Scott, Yale University.

3:30 P.M. Conference on English. Gerrard Hall. Sada A. Harbarger, *Chairman.*

Some Special Problems in the Teaching of English to Students of Engineering.

Conference on Drawing. 300 Phillips Hall, Thos. E. French, *Chairman.*

Conference on Mechanics. 319 Phillips Hall, A. P. Poorman, *Chairman.*

Results of the Wisconsin Session. E. R. Maurer, University of Wisconsin.

Open Questions. S. M. Woodward, State University of Iowa.

Discussion:

LeRoy Tucker, Clemson College.

G. P. Boomsliter, West Virginia University.

Report of the Permanent Wisconsin Committee, S. M. Woodward.

Conference on Electrical Engineering. 353 Phillips, Hall, Paul Cloke, *Chairman.*

6:30 P.M. Annual Dinner, Carolina Inn.
R. L. Sackett, President of the Society, presiding.
Presentation of the Lamme Medal.
Address: Hon. O. Max Gardner of North Carolina, introduced by Archibald Henderson.

THURSDAY, JUNE 28, 1928

9:00 A.M. Third Session. Gerrard Hall, Thos E. French, Vice-President, presiding.
Reports of Committees:
Electrical Engineering.
English.
Drawing and Design.
Mechanics.
Presidential Address: The Changing Emphasis in Engineering Education. R. L. Sackett, Dean, School of Engineering, The Pennsylvania State College.
Discussion:
H. J. Hughes, Harvard University.
C. H. Mitchell, University of Toronto.
C. C. Williams, State University of Iowa.
Election of Officers.

11:00 A.M. Adjournment.

1:00 P.M. Luncheon at the State College of Agriculture and Engineering at Raleigh. C. E. Magnusson, Vice-President, presiding.
Address of Welcome. Eugene C. Brooks, President.
Address. Angus Wilton McLean, Governor of North Carolina.

3:00 P.M. Fourth Session. C. E. Magnusson, Vice-President, presiding.
Scholarship of Students on a Basis of Social Grouping. L. L. Vaughan, North Carolina State College.

Agricultural Engineering. J. B. Davidson, Iowa State College.

Discussion.

Study of Land Grant Colleges. A. A. Potter, Purdue University.

Report of Resolutions Committee.

Adjournment.

6:00 P.M. Typical Southern Barbecue. Cape Fear Plant of the Carolina Power and Light Company.

MINUTES OF THE THIRTY-SIXTH ANNUAL MEETING OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL, N. C., JUNE 26, 27, 28, 1928

The thirty-sixth annual meeting of the Society for the Promotion of Engineering Education was held at the University of North Carolina, Chapel Hill, N. C., Tuesday, Wednesday, and Thursday, June 26, 27, 28, 1928. Three sessions were held in Gerrard Hall at the University and one in Pullen Hall at the State College of Agriculture and Engineering. Robert Lemuel Sackett, Dean of the School of Engineering, Pennsylvania State College, President of the Society, presided at the meetings. There were 359 members and guests registered.

TUESDAY, JUNE 26, 1928

At 10:00 A.M. on Tuesday, June 26, 1928, the teachers of Drawing held a conference in 300 Phillips Hall with Thos. E. French, Vice-President of the Society and Chairman of the Committee on Drawing, presiding. The subject of this conference was Descriptive Geometry.

At 2:00 P.M., the thirty-sixth annual meeting of the Society was opened in Gerrard Hall by President R. L. Sackett who introduced Harry Woodburn Chase, President of the University of North Carolina, who welcomed the Society to the University. He presented President Sackett with a gavel which had been made from wood taken from the oldest state university building in America, the old East Building of the University of North Carolina. President Sackett responded to the address of welcome and accepted the gavel of walnut "which typifies in a peculiar way the beauty of education and the durability of it in material; the polish which it takes on is typical of that which does, or should come through the channels of education."

Herbert Schofield, Principal, Loughborough College, England, was scheduled as the first speaker but was unable to be present at the meeting. G. M. Braune presented "A Review

of the Report of the Board of Investigation and Coordination as Related to the Engineering School at the University of North Carolina." Associate Director of Investigations, H. P. Hammond, read his paper on "A Practical Step toward Improving Methods of Teaching." These papers were discussed by E. R. Maurer, LeRoy Tucker, T. F. Hickerson, and W. J. Risley.

The President appointed a committee on resolutions consisting of W. S. Rodman, Chairman, J. R. Lapham, G. W. Munroe, W. J. Risley, and A. M. Dudley.

At three-thirty the teachers of mechanics held a conference in Phillips Hall with J. E. Boyd presiding. Papers were presented at this conference on "How Much Dynamics Should be Included in a Course in Engineering Mechanics?" by N. C. Riggs; "The Difficulties of the Embryo Teacher of Mechanics and How They Might be Removed," by E. W. Rettger; "Mechanics Accessories," by W. J. Risley.

The teachers of Electrical Engineering, under the direction of Paul Cloke, held a conference at the same time.

Miss Sada A. Harbarger presided at the meeting of teachers of English held at 3:30 P.M.

At five o'clock the members and guests were driven to Duke University at Durham, N. C. They were personally conducted over the campus and the many new buildings now under construction were shown to them and explained in great detail. After the inspection we were guests of Duke University at dinner and a social hour.

WEDNESDAY, JUNE 27, 1928

The second session of the convention convened in Gerrard Hall at nine o'clock with President Sackett presiding. The first speaker was Clair V. Mann, Missouri School of Mines, who spoke on "Placement Examinations." This paper was illustrated. The paper was discussed by T. M. Focke, and E. L. Grant. Thorndike Saville presented a paper on "Development in Sanitary Engineering at the University of North Carolina" which had been prepared jointly by himself and H. G. Baity. "College Experience in its Relation to

Achievement in Industry" was presented by R. I. Rees of the American Telephone and Telegraph Company. This paper was also illustrated.

Charles F. Scott, Chairman of the Board of Investigation and Coordination, reported for that body and also gave the report that the Board that morning had accepted the invitation from Purdue University to hold a summer school on Mechanical Engineering at that institution in 1929. W. E. Wickenden, Director of Investigations for the Society, presented his report.

A two o'clock there was a meeting of the Institutional Division in Phillips Hall with Vice-President C. E. Magnusson presiding. At this meeting the Division voted to recommend to the Society that the dues of institutional members be raised to $15.00 per year. The Chairman of the Board of Investigation and Coordination, Charles F. Scott, reported that the Board had set aside in its budget this year $2,000 for a study of shop instruction contingent upon the ability to raise additional funds; $1,000 for a study of personnel projects contingent upon the desire of the Institutional Division to appoint a committee; $1,200 for an investigation of secondary schools. W. E. Wickenden, Director of Investigations for the Society, presented a paper on "Functions and Organization of the Institutional Division." This was discussed by H. J. Hughes, A. A. Potter and C. F. Scott. The Division voted to recommend to the Council that two committees be appointed under the auspices of the Institutional Division to cooperate with the staff in certain inquiries into personnel practices and in setting up a joint committee with representatives of secondary schools.

The second conference on Mechanics convened in Phillips Hall at 3:50 P.M., with A. P. Poorman presiding. E. R. Maurer presented a paper on "Results of the Wisconsin Session"; S. M. Woodward read his paper on "Open Questions."

The second conference on English was held in Gerrard Hall at 3:30 P.M., with Miss Harbarger presiding. The topic for discussion was "Some Special Problems in the Teaching of English to Students of Engineering."

The second conference on Drawing was held in Phillips Hall at 3:30 P.M., with Vice-President T. E. French presiding.

The second conference on Electrical Engineering convened in 353 Phillips Hall at 3:30 P.M., with Paul Cloke, Chairman, presiding.

The annual dinner of the Society was held in Carolina Inn at 6:30 P.M., and President R. L. Sackett presided. A new feature, inaugurated this year, was the awarding of the Lamme medal. A short biographical sketch of the donor, Benjamin Garver Lamme, was presented by his co-worker, Charles F. Scott. President Sackett read that portion of the Lamme will which provided for the medal. C. S. Coler, Chairman of the Committee on Award, presented the report of that committee which named George Fillmore Swain, Harvard University, as the first recipient. Professor Swain was not in attendance due to ill-health and Dean H. J. Hughes was asked to receive the medal for Professor Swain. Later the following telegram was sent to Professor Swain: "The Society for the Promotion of Engineering Education has awarded you the Lamme medal for distinguished achievement in engineering training and sends its warmest regards with this recognition of your long service to engineering education." Professor Swain wired "Great honor conferred which I appreciate most humbly. Am proud to be a member of the Society for the Promotion of Engineering Education."

Harry Woodburn Chase, President of the University of North Carolina, was the chief speaker of the evening and selected as his subject "The Significance of the Engineering Attitude in Modern Life."

The Nominating Committee presented the following report for officers of the Society. Upon motion, the Secretary cast the ballot of the Society for the officers named and they were unanimously elected.

For President: D. S. Kimball, Cornell University.

For Vice-Presidents: C. C. Williams, University of Iowa; G. M. Braune, University of North Carolina.

For Secretary: F. L. Bishop, University of Pittsburgh.

For Treasurer: W. O. Wiley, John Wiley & Sons, New York City.

Members of the Council to serve for three years: Paul Cloke, University of Maine, Carl S. Coler, Westinghouse E. & M. Company, R. C. Disque, Drexel Institute, T. M. Focke, Case School of Applied Science, H. S. Rogers, Oregon State Agricultural College, Chas. H. Warren, Yale University, J. J. Wilmore, Alabama Polytechnic Institute.

President Sackett introduced the President-Elect, Dexter S. Kimball, who expressed his appreciation of the great honor conferred upon him.

THURSDAY, JUNE 28

The third session of the convention was held in Gerrard Hall with Thomas E. French, Vice-President of the Society, presiding. The first order of business was the reports of committees. The following reports were presented: Electrical Engineering by Paul Cloke; English by Sada A. Harbarger; Drawing and Design by R. P. Hoelscher; Mechanics by A. P. Poorman.

Robert L. Sackett, Dean of the School of Engineering of the Pennsylvania State College, delivered his Presidential Address, "The Changing Emphasis in Engineering Education." This address was discussed by H. J. Hughes and C. C. Williams.

The papers by R. I. Rees and W. E. Wickenden presented at the morning session on Wednesday were then discussed by E. A. Hitchcock, C. L. Dawes, D. C. Jackson, Jr., C. C. Williams, J. L. Felgar, O. K. Harlan, E. B. House, R. L. Sackett and by R. I. Rees and W. E. Wickenden.

The report of the committee on Relation of Engineering Colleges to Railroads was read by title. In the absence of the chairman, A. H. Fuller, the Secretary read the progress report of the Committee on Civil Engineering; the report on Industrial Engineering, and the report on the Standardization of Technical Nomenclature. The Treasurer, W. O. Wiley, presented his report accompanied by the auditor's statement. Upon motion this was accepted and ordered printed. The Secretary, F. L. Bishop, presented his report which was accepted and ordered printed. The Secretary presented the recommendation of the Council that By-Law four of the Con-

stitution of the Society be modified to read that individual dues shall be $5.00 per year, and that institutional dues shall be $15.00 per year. Upon motion the recommendation was adopted.

The fourth and last session of the thirty-sixth annual meeting was held at the State College of Agriculture and Engineering at Raleigh, N. C., with Vice-President C. E. Magnusson presiding.

Preceding the meeting the members and guests were entertained at luncheon at the Sir Walter Scott Hotel, Raleigh, where in the absence of President Brooks who was in Europe, Thomas E. Brown, Director of the Summer School and Dean of the College of Education, welcomed the Society to the College. President Sackett responded for the Society. In the absence of the Governor of the State, Wade Marr, Director of the North Carolina Bankers Association, addressed the group.

The fourth regular meeting was held in Pullen Hall. The first paper was one by L. L. Vaughan on "Scholarship of Students on the Basis of Social Grouping." J. B. Davidson read his paper on "Agricultural Engineering."

Dean A. M. Greene, on behalf of the Council of the Society, presented the assistant secretary with a bunch of beautiful North Carolina flowers in appreciation of the work which she renders to the Society.

The Committee on Resolutions presented the following report which was unanimously carried by a rising vote:

The Society for the Promotion of Engineering Education assembled for its thirty-sixth annual meeting at the University of North Carolina, having enjoyed in fullest measure the proverbial hospitality of the Old North State, and being of the unanimous opinion that this meeting has provided an occasion of great value to its members through the excellently planned and carefully matured program as well as by the accompanying social and entertainment features so graciously provided for its members and guests; and having a keen appreciation of the untiring efforts which have contributed so measurably to bring about such a delightful blending of serious work and unadulterated pleasure, desires to record in an all too inadequate manner its very hearty and deep appreciation of the manifold courtesies and privileges of which it has been the recipient.

Therefore Be It Resolved: That the Society for the Promotion of Engineering Education extends its grateful thanks to President Chase, the officials and faculty of the University of North Carolina for their unceasing and most cordial efforts to make this visit memorable; to the Local Committees, and especially to the Ladies Committees, for the excellent manner in which all needs and desires were so completely foreseen and cared for; to President Few and the officials and faculty of Duke University for the opportunity afforded to visualize so completely the remarkable program of growth now in process and for the bounteous entertainment provided; to President Brooks and the officials and faculty of the North Carolina State College of Agriculture and Engineering for their cordial reception and entertainment tendered; to the management of the Carolina Inn, the Washington-Duke Hotel, and the Sir Walter Scott Hotel for the many courtesies extended in caring for the physical well-being of members and guests; to the residents of Chapel Hill who so hospitably opened their doors and gave shelter; to the Durham Branch of the American Tobacco Company for the appropriate souvenirs so generously provided; to the Chambers of Commerce of Durham and Raleigh, and to those state and city officials and other individuals who joined in the reception and the entertainment and provided the mementos of the respective cities; to the management of the Carolina Theatre for providing such pleasant entertainment for the ladies and the children; to the Coffey-Miller Players for their most pleasing presentation of plays; to the Carolina Power and Light Company for the most enjoyable Barbecue; to the Chapel Hill Country Club for its provision for the visiting ladies; to the Hope Valley Country Club and the Raleigh Country Club for privileges so kindly made available to Society members; to the Police officials and personnel of Durham and Raleigh who contributed so effectively to the safety and comfort of the automobile trips by their efficient supervision of traffic.

(Signed) W. S. Rodman,
J. R. Lapham,
G. W. Munroe,
W. J. Risley,
A. M. Dudley.

A. A. Potter, Purdue University, presented a paper on "A Study of Land Grant Colleges."

There being no further business the thirty-sixth annual meeting of the Society for the Promotion of Engineering Education adjourned *sine die*.

F. L. Bishop,
Secretary.

AN EVALUATION OF PLACEMENT EXAMINATIONS

BY CLAIR V. MANN,*

Professor and Head, Department of Engineering Drawing, Missouri School of Mines, Rolla.

It is interesting to note that more and more the administrations of American colleges and universities are concerning themselves with the problem of ascertaining at an early period in the college student's career just what sort of a creature he is, what his chances are of succeeding in university work, whether this will hold good for one, for two, or perchance for four years of the course. More and more does it seem necessary to diagnose causes of failure in scholarship, and to remedy them while failure is impending, if that can be done—otherwise to get rid of the "dead timber." True economy in the expenditure of public funds has demanded and justifies such a procedure, in particular in the State institution.

The evaluation of the worth and effectiveness of the Placement Examination as an instrument for predicting success in scholarship involves a consideration of the peculiar place which such examinations occupy in the general scheme of mental and physical measurement, and among other factors, connected with scholastic success or failure of students.

The process of learning has been said to be conditioned upon five primary things, as follows:

(1) The nature of one's bodily equipment in general;
(2) The nature of the stimulus, or situation, or the problem—in this instance, the whole university environment;
(3) The condition of the bodily equipment at the moment;
(4) The condition of the mental equipment at the moment;
(5) The nature of one's previous experiences.

* Presented at the 36th anual meeting of the Society, University of North Carolina, June 26–28, 1928.

In short, what the university is now trying to measure in its prospective students includes in a general way physical fitness; intellectual fitness; emotional temperament and social fitness; emotional complexes and conflicts; motor capacities; and study methods. In the case of the engineering college, it is attempting to know how well prepared the student is for the fundamental courses and what special aptitude and training the student may have for the profession of engineering. Finally, there is a need of knowing what effect teaching methods have on the student.

Now it needs clearly to be emphasized that scholastic success is dependent not upon one quality only, such as intelligence, aptitude, or previous training, but also upon such qualities as energy, and the ability and willingness to use it; upon perseverance; determination; and perhaps a primary essential, interest, or "drive." The student with moderate ability, but with determination and a steady, purposeful "drive" may well succeed and be a better student and engineer than is the highly intelligent, gifted student who has no such drive, or who is lazy. It needs to be emphasized that there are many other, and some very important factors, which enter into scholastic success or failure, besides the aptitude for a special course, or training for it, or high intelligence in general.

I point this out at this time so that the Placement Examination may not be unduly discounted if it does not predict perfect success. The Placement Examination *should* be held responsible if it fails to measure correctly *aptitude* or *ability*, but it is not responsible for the failure of the student to *exercise* those qualities, if he has them.

We may now proceed to define the purpose of the Placement Examination, without fear that it may be taken for something that will predict scholastic success under any and all conditions, and in direct contravention of some. The Placement Examination has been constructed to cover a single field of knowledge. It is supposed to differentiate between training in a subject and natural aptitude or fitness for that work. It will ordinarily be conducted by the department concerned. It will give adequate knowledge about the student's place and

needs in the course. It will enable accurate sectioning to be done on the basis of ability. And a complete "battery" of such Placement Examinations will yield a composite score as significant as that obtained by a well designed intelligence test.

Here we have stated the principles on which the Iowa Placement Examinations are constructed. It is to be noted that no claim is here made that the Examinations will predict scholastic success under any and all conditions, and in spite of the operation of major adverse factors. The above definition indicates not only the character of the Placement Examination, but fixes it in its peculiar place in the general system of tests and measurements that the modern university is applying to its entering students.

One other peculiar property of the Iowa Placement Examinations is to be noted, and that is that such tests are quite highly objective—that is, each question is as nearly as possible capable of one interpretation and one answer only. A large number of such questions is provided, and the student answers by underlining or supplying a word, or by indicating by a simple mark whether questions are true, or false, and so on. It does not require a well trained discriminating teacher, to grade (score) such tests. All are scored in exactly the same way—by means of a key. There is no chance of giving a point to one student, or of taking it from another. Such tests, when properly validated, as the Iowa tests have been, furnish a very reliable method for comparing relative ability of the individuals in a group as related to any specific course in the curriculum.

The discussion of any instrument of measure must, in the last analysis, involve an understanding of the units in which it measures, and must consider the standards by which the value of these units are fixed. The Placement Examination is an instrument used in the process of mental educational measurement. The question is, in what units does it measure, and by what standard are its results to be judged, and how reliable is that standard? We have in the Bureau of Standards at Washington highly precise "standard" units of meas-

ure for fixing the standard lengths of the meter and the yard, and from them all the other units we use in linear measure. What is the standard by which we judge the effectiveness of the Placement Examination? The answer is, "college grades," a widely variable quantity, even in the same department in the same university. And it must be clearly pointed out there can be no more reliability in the results of measuring by Placement Examinations than there is in the standard with which Placement results are compared. Just as there can be no great reliability in measuring potential differences with a volt-meter which has not been compared with a comparatively unvarying standard of measure.

In this connection, it is to be noted that most of the writers and students who have evaluated Placement Examinations, and other test types, on the basis of college grades as the criterion, have finally concluded that further improvement of the Placement Examination or other test will yield no further appreciable results until the criterion—college grades—is itself made more reliable, principally through the use of objective type testing procedures, and through such standardization of tests as may be possible. This opinion is becoming increasingly insistent.* In other words, we do not have, in higher education, any standard of educational measurement comparable to the "standard meter" of the Bureau of Standards, and many seem to feel that such a standard is not to be devised. The bald fact is, however, that with the materials that we now have available, we could manage to do a far better job of grading than we *do* do; and further researches in this direction are proceeding, and promise much for the future.

It is apparent, then, that at this stage of events we do not need to concern ourselves unduly if we find that the Placement Examination does not predict success with the highest possible, or absolute, certainty. Not the most optimistic of its advocates would expect that. When we come to under-

* If any one is interested in this aspect of my paper, I refer him to recent researches (6) of Dr. Ben D. Wood and his associates, of Columbia University.

stand the situation in this way, we will find the atmosphere vastly cleared.

The Missouri School of Mines and Metallurgy, which institution I represent, was one of the institutions that, with others, cooperated with this Society in the trial administration of the Iowa Placement Examinations during the 1925–26 school year. The results obtained at that time were studied, and a fairly good correlation between them and term grades in chemistry, English, and mathematics was noted. The results for our School were published with those of the other cooperating schools in reports (1) prepared by Dr. George D. Stoddard, of the University of Iowa. Other reports (2) (3) have been published in various educational journals, and (4) in our own JOURNAL OF ENGINEERING EDUCATION.

Table I displays some interesting data relative to the effectiveness of Placement Examinations in predicting scholastic success in general, over a four year period of college work.

TABLE I.

CORRELATION OF PLACEMENT EXAMINATIONS AND SCHOLARSHIP RECORDS FOR FOUR YEARS. MISSOURI SCHOOL OF MINES. CLASS OF 1928.

Cumulative Standing in Placement Examinations	Group Median Score	Scholastic Standing at End of Four Year Period									
		Grds. A & B		Grds. C & D		Grd. F (fail)		Out of School for Causes other than Scholarship		Total Failures and "Out of School"	
		No.	%	No.	%	No.	%	No.	%	No.	%
Highest 5th..	68	7	25	12	42.8	4	14.3	5	17.9	9	32.2
Second 5th...	56	4	14.3	10	35.8	6	21.4	8	28.5	14	49.9
Third 5th....	49.6	2	7.2	10	35.8	3	10.7	13	46.3	16	57.0
Fourth 5th...	42.8	0	0.0	11	39.2	1	3.6	16	57.2	17	60.8
Fifth 5th....	32.6	0	0.0	8	28.5	7	25.0	13	46.5	20	71.5
Total Group.	49.6	13	9.3	51	36.3	21	15.0	55	39.4	76	54.4

The "fifths" designated in Table I were those determined by scores made and combined from all placements a student took. Note decreasing measure of success attending drop in level of ability as predicted by the Placement Examinations.

As a result of the published reports referred to, and from our own experiences, the Faculty of our School came to have considerable confidence in the Iowa tests, as an instrumentality for differentiating the ability levels of freshmen students. In looking over the several experimental projects recommended by the Board of Investigation, the interest of the Faculty became centered in trying out a program designed to single out the distinctly superior students, in order to provide for them unusual opportunity—the best at the command of the institution. It was decided to lay out a systematic program of experimentation in this line that might perhaps extend over a period of years, depending upon the degree of success attained at the several stages in the program. It was proposed to apply scientific experimental method to all parts of the program, so far as that could be done. That experiment is now well under way, and the first year has been successfully closed.

First of all, it was decided to apply the experiment more intensively in the freshman year than elsewhere, and to a limited extent in the sophomore year. The present program does not definitely include the upper two years, although it may later on, as the 1928 freshman class progresses through the institution. The administrative procedure is vested in a specially created Committee of the Faculty to have major control of the work of the two lower years.

Specifically, the School of Mines experiment required setting up of comparatively simple personnel studies and records. The system adopted collects moderately detailed personnel information concerning every student in the institution. Staff opinion is secured as to the intelligence, energy, initiative, leadership, character and personality of each student, the rating being superier, mediocre, or inferior. Our program involved administration of the Iowa Examinations as a means of segregating superior, mediocre, and inferior students, and as a basis for class sectioning on these levels. We constructed a local Placement Examination in Aptitude for Engineering Drawing, to be used in the same way. We were

required to adapt our methods of teaching to fit these several ability levels.

Another thing that the situation apparently required was reinstatement of the semester final examination, for some years discontinued as unsatisfactory. These final examinations, together with periodic quizzes, involved for some departments, notably my own, an entire change of testing procedure. The change consisted in adoption of the "new type," objective, quiz and examination, in place of the old, "subjective" type. All departments that have thoroughly tried out this new style of examination are enthusiastic in its support. Particular advantages of such tests are to be found in the elimination of the teacher's especial friendliness or animosity for particular students; in the grading of all students by exactly the same standard; in holding to the same standard of grading throughout all classes of a department; in measuring and reporting actual, instead of theoretically possible, achievement of a student in a given subject; in the thoroughness of consideration of quiz material before administration; and in the ease and speed of grading. Such examinations show the staff at all times any changes that are going on in any individual group of students in respect to increased or decreased achievement of any student.

In a paper such as this I cannot hope to describe all the interesting details of our experiment and the experiences arising from it the past year. Neither can I present final conclusions from a scientific experiment still in progress. It may be permissible to say, however, that we are now assured that the Iowa Placement Examinations, along with our locally designed Aptitude Test in Engineering Drawing, are well enough designed to enable us to select the upper levels and the lower levels of student ability with remarkable precision.

Without attempting to present detailed correlations for every course, I may summarize this information by saying that in no one of the subjects in which tests were given—Chemistry, English, Engineering Drawing, Mathematics, and Physics—was there a coefficient of correlation of less than .626 (Pearson product-moment), which was the value for our Drawing

test. This correlation is higher, on the average, than shown by most of the reports so far published; specifically, higher

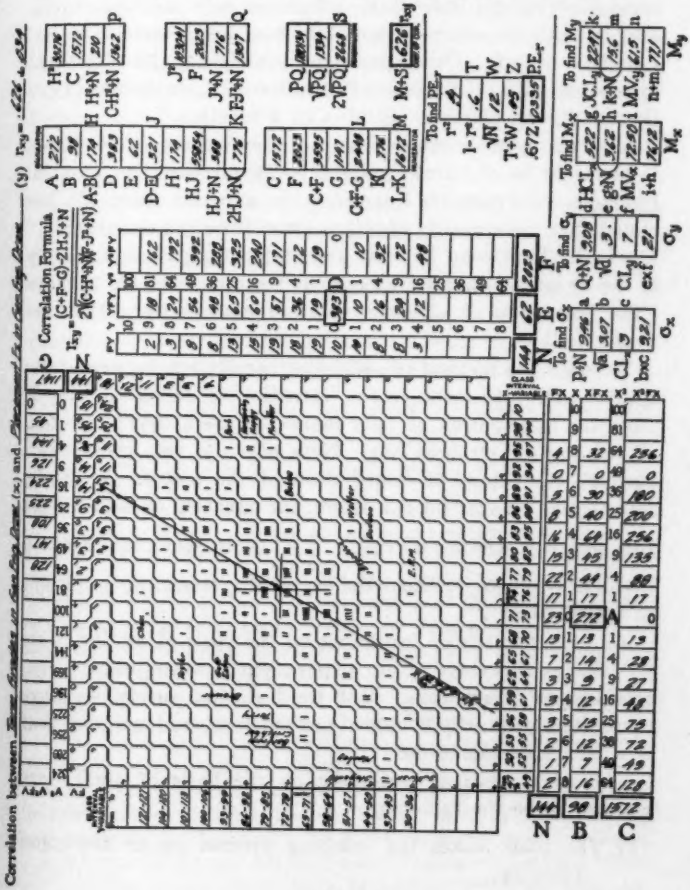

FIG. 1.

than those shown for students at the University of Minnesota, reported (4) by Mr. T. A. Langlie in the JOURNAL OF ENGI-

NEERING EDUCATION for May, 1927. Our first term correlation in Mathematics exceeded .700. We find that the Placement Tests reveal individual differences to a marked degree, and in this we agree with conclusions also reached in Mr. Langlie's report. These results are gratifying, and in general agreement with the findings of Dr. Stoddard, published (1) in the University of Iowa "Studies in Education."

If other opinion respecting the effectiveness of the Iowa tests would be of value, I might point out that Dr. Percival Symonds, of Columbia University, in a recent work (5) has stated that "the results of this work at Iowa are remarkable." Dr. L. L. Thurstone (7) has also stated that, from his study of the situation, the Iowa Placement Examinations are perhaps "the best form of objective content examinations that are available."

To show the method of obtaining correlation between term grades and placement scores, attention is called to Fig. 1. Note the distribution of tally marks, in the general direction of the sloping straight line. Note also the two axes drawn through the center of distribution of the scores. With the intersection of axes for the origin, the equation of the straight line shown is written $y = .627 \frac{\sigma_y}{\sigma_x} x$ ((y is equal to (sigma y divided by sigma x) times the variable x, times the coefficient of correlation)).

As to the merits of sectioning on the basis of ability, I am not able at this stage of our experiment to state positive conclusions, or convictions. But we feel that surely we have more than ordinarily benefited our superior students, and that is what we set out to do.

The advantages of sectioning on the basis of ability are claimed to be the following:

(*a*) The plan makes the teaching process easier and more effective.

(*b*) It facilitates student learning.

(*c*) It keeps each student, superior or inferior, fully occupied but not overcrowded, working at the level of his own ability.

(*b*) It avoids making a "loafer" of the gifted student.

(*c*) Gifted students are susceptible to special educational methods, just as rich ores in mining merit different treatment in smelting from that accorded to medium grade or inferior ores.

In the opinion of some, objections to sectioning are as follows:

(*a*) That the idea is undemocratic. That it tends to promote an educational aristocracy.

(*b*) Students recognize the distinctions made by sectioning, and are given a consciousness of superiority or of inferiority that is harmful.

(*c*) Gifted students tend to overwork when in a group of like ability.

(*d*) Mediocre or poor students often learn as much from a gifted student as from the teacher of their class.

As exemplifying student sentiment in regard to the advantages of the plan as we have tried it, I quote from the written opinions of several students handed to me at the close of this year's work:

Student A: "I think the idea of sectioning according to ability to do work in a given course is a very good one. It gives the man who is superior a chance to do his best work in a course. He is not held back by students who cannot work as fast as he can. On the other hand, a man placed in the lower section because he cannot work so fast is not over-rushed in the course by being in a class where the other members are so much ahead of him in the work.

"The placement examination is a fairly good method of sectioning men according to their ability. A man, however, may show by his work that he deserves to be in a higher section than that in which he was classed by his Placement Examination."

Student B: "Sectioning men according to their ability is, I think, the best means of grouping them into classes. Although it is true that keen competition stimulates an inferior student into greater activity, it is also true that he may not be stimulated enough to keep him 'above par.' A man, too, who has to hustle to compete successfully with classmates of superior ability is likely to overburden his mind, with the result that all benefit that might be derived from a course is lost as soon as it is completed.

"A man competing with men of his own ability knows that his suc-

cess or failure is due entirely to his own efforts. One, therefore, who desires to succeed, and who finds that his work is inferior, will conclude that he has not put forth his best efforts and will endeavor to remedy the situation."

Student C: "I think sectioning of students according to ability is an excellent thing. As far as I am concerned, I feel that I have been sectioned with men of my ability. I have been kept busy, whereas I might have been tempted to waste my time if I had been sectioned with a group where the work would be easy for me.

"In many courses the sectioning is also helpful to the professor. He does not have to contend with a mixture of some brilliant and some weak students under the sectioning plan. It enables him to put his 'stuff' across to the students according to their ability to absorb it. The whole plan is of a great importance and I hope it stays at least as long as I am enjoying an education at the Missouri School of Mines."

This discussion would be incomplete without drawing attention to some of the byproducts of our interesting program. One thing has been very evident—every instructor who has been involved in the program for gifted students or in sectioning classes the past year at our institution has been strictly "on his toes." The situation has been tremedously stimulating to the teacher, as well as to the student. Teaching has been better, more cooperative. Freshman personnel problems have been handled with far more deliberation and understanding. A whole field of most interesting problems involving further research has been opened up. A critical attitude toward present teaching method has been engendered. The validity of "grades" has been called into question, and research is in progress directed toward the development of scientifically constructed objective type tests in basic subjects in science and engineering.

As we have pointed out, before we can hope to get greater reliability in placement examinations, we must secure greater reliability in the term grades against which they are correlated, and the objective type examination occupies the keystone position in that situation. Between different instructors, different departments, and different schools, we are today employing a multitude of different and unstandardized "yardsticks," some of them WIDELY different from the average.

What we badly need is some fairly uniform, "standard" grading practice, based upon as purely objective testing procedures as can be devised. A great deal is already known that could be utilized in constructing such standards, and much more can be found through researches initiated and directed by the engineering colleges and by this Society. The system of employing letter grades is entirely inadequate for the purposes of obtaining correlations between placement tests and term grades. The old per cent. system of grades was far better for this purpose. There are other new, more modern systems, that deserve a tryout. Among them is the percentile technique of recording student achievement in examinations and courses.

I suspect that teachers in the engineering college are presently coming to the point where it will be clearly recognized that the pressing problems of the two lower years are not at all the same as those of the two upper years. It appears to me that the problems are quite vitally different, and call for radically different training in the teacher. That is so, primarily, because the teacher in the two lower years has the tremendous task of making the high school student over into a university student. This is worthy of the best effort that is in the most skilled teacher that can be procured. The ideal teacher of freshmen and sophomore students will be the man with generous background in engineering, both in education and practice; who has, in addition, facility of verbal expression, sympathy, training in psychology, mental measurement, and personnel work, in quantity sufficient to appreciate properly and to solve the many perplexing problems of lower classmen. Such men will bring to their work a knowledge of how to construct all the necessary placement or objective type tests, and to check up on those made by others. They will be of the inspirational order, and will be able to turn many an impending student failure into success.

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PLACEMENT TESTS AND THE HIGH SCHOOLS*

BY T. M. FOCKE,

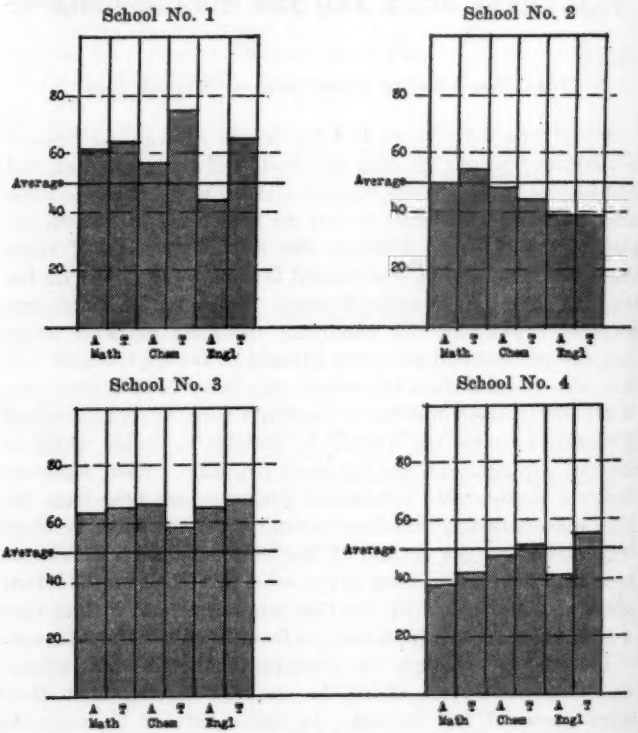
Dean, Case School of Applied Science, Cleveland, Ohio

It has been the custom at Case School of Applied Science to construct graphs showing the results of the placement and intelligence tests for each student. Some of these have shown such marked characteristics that we have tried to find an explanation for them. Perhaps the most important of these characteristics is when the student is consistently lower on the training than on the aptitude tests. There are of course two ways of explaining this condition, the most probable being that the student did not exert himself in the high school, but it is also possible that the school may have been a poor one. With only a small number of students from any given school it would of course not usually be possible to decide which of the two explanations was the more probable. Case, however, draws a considerable number of students each year from the high schools of Cleveland and vicinity and we have therefore been collecting the results of the placement tests of all the men who have come from given schools. We have had four years of experience with the placement tests and in that time a number of schools have sent us from 25 to 80 students each.

In order to compare the training at the different schools the percentile scores of all the students coming from them were averaged test by test. In order further to make the comparison of training and aptitude scores as valid as possible only those were included where the student took both the tests of a particular subject. These averages were then plotted. The vertical scale on these figures gives the average percentile standing of the group. It would represent the percnt of the whole freshman group that stood lower on the particular test than the average man from the given high school.

* Presented at the 36th annual meeting of the Society, University of North Carolina, June 26–28, 1928.

For the purposes of this paper only four schools are included.

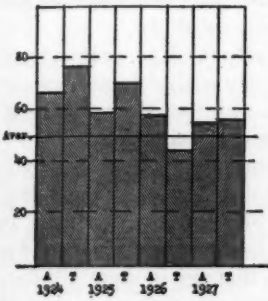


Diagrams showing the average percentile standing of graduates of four high schools on the Iowa Placement Tests. Covers all men entering from 1924 to 1927 who took the tests.

School No. 1 is an academic high school in a residential section of the city. Such a large percentage of its graduates go to college that it has for years maintained classes for preparation for the entrance and prize scholarship examinations. The students have been very successful in winning prize scholarships. Among others they have won 12 out of the 21

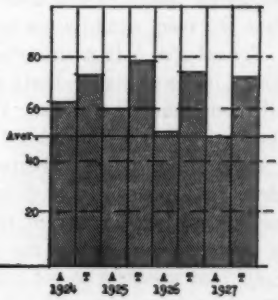
offered by Case to graduates of the Cleveland high schools in the last seven years. The diagram shows that except in English the aptitude is higher than the average but that in every

Mathematics at School No. 1

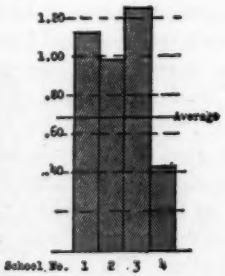


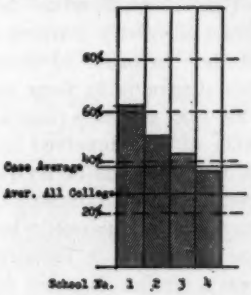
Point Ratio for First Term for the years 1924 to 1927 incl.

Chemistry at School No. 1



Percentage of entering freshmen who graduated on time. Classes 1925 to 1928 inclusive.





case the training is much higher. The English aptitude is probably low on account of a number of students of foreign extraction.

School No. 2 is a technical high school in about the same section of the city as No. 1 but it draws much more heavily from families of foreign extraction than does No. 1. The diagram does not show the strength of No. 1 but perhaps on account of the technical emphasis of the work done there its students

as a rule do quite satisfactory work with us as will be shown later. I may remark in passing that the graduates of this school and also of the other technical schools of the city do not seem to do themselves justice on the placement and intelligence tests. Their average performance is always higher than the tests would seem to indicate it should be.

School No. 3 is a suburban high school. The people from whom it draws its students are all fairly well-to-do and almost all from American stock. It will be seen that the aptitude of the students is high and the training quite satisfactory.

School No. 4 is a private institution maintained by a religious organization. It draws from members of this denomination only and many of them are of foreign extraction. It is probable that we do not get the best of their students for each year we seem to get one or two that are in quite a different class from the rest. At any rate our figures show that the material is rather poor quality and while the school improves it somewhat, it is still below the average.

Let us return to school No. 1. It will be noted that in the diagram chemistry training shows a marked increase over the aptitude. In order to show that this is no accident I have drawn diagrams to show the relation between the two tests for the four separate classes that are involved. Of course the number of men involved is not large, from 5 to 10 for each class, but there can be no question but that chemistry is being exceedingly well taught. I may add that a very large percentage of the students who come to us from this school take either chemical or metallurgical engineering. I have also drawn a similar diagram for mathematics. They had had a very fine teacher of this subject but lost him to one of the suburbs two years ago. The effect is quite apparent.

The next diagram shows results of the first term of college work for the graduates of the four high schools for the same four years. We give three points for each hour of "A" work, two points for "B," one for "C," none for "D," minus one for "E" and minus two for each hour of failure. On this basis the ratings of the schools are:

School No. 1 ..... 1.13 points per hour
School No. 2 ..... 0.99 points per hour
School No. 3 ..... 1.25 points per hour
School No. 4 ..... 0.43 points per hour
All freshmen ..... 0.69 points per hour

It will be seen that these grades follow quite closely the results of the placement tests except that School No. 2 seems to have done better than the test grades would seem to warrant.

There is one more set of figures regarding these schools that is worth considering, but unfortunately it does not cover the same students that are involved in the other diagrams. This is the graduation ratio, the percentage of students who enter the freshman class that graduate four years later. The classes are those that graduated in the years 1925 to 1928 inclusive. From

School No. 1 62% of the men who entered graduated on time.
School No. 2 50% of the men who entered graduated on time.
School No. 3 44% of the men who entered graduated on time.
School No. 4 37% of the men who entered graduated on time.

The college average for the same classes was 38 per cent. There is reason to believe that the ratio is increasing for School No. 3 and decreasing for No. 4.

It will be remembered that the S. P. E. E. investigation showed that about 28 per cent of the entering students were graduating on time from all the institutions of the country. It seems to the writer that the figures given above show pretty definitely that this ratio could be very greatly increased if we all could draw our students from schools as good as the first three. It may be added that if the students who came to Case from the schools of Cleveland and vicinity were eliminated the Case graduation ratio would also be 28 per cent.

THE LAND GRANT COLLEGE SURVEY*

BY A. A. POTTER,

Dean of the Schools of Engineering, Purdue University, and Consulting Expert Land-Grant College Survey

The Association of Land-Grant Colleges and Universities, in May 1926, invited the Bureau of Education of the U. S. Department of Interior to make a survey of the land-grant colleges, Congress provided for an appropriation of $117,000 to the Bureau of Education for a two-year study of the accomplishments, the status and the future objectives of the land grant type of education.

The educational conception of the land grant college type of education has developed gradually from 1825 to 1860. These colleges are the result of a neglect of the industrial classes by the then existing institutions of higher learning. The urge of those interested in this type of education was to establish colleges and universities which shall give to the industrial classes a scientific and practical training equivalent in all respects to the literary training already given as a preparation for the learned profession of that day, which included law, medicine and religion. The objectives of the advocates of the Land Grant Act were increased production (in agriculture and industry) and professional recognition. These colleges have contributed greatly toward a sense of responsibility on the part of the States for technical education and a realization that education is a developmental function in which the state and the nation may cooperate advantageously to the public.

To secure data bearing upon land grant college education questionnaires have been or are being prepared by the United States Board of Education covering the following schedules: Graduates and ex-students; resident students; staff; institutional control and finances; institutional administration

* Presented at the 36th annual meeting of the Society, University of North Carolina, June 26–28, 1928.

and organization; registrar's data; library; sub-collegiate instruction; instruction in specific fields such as agriculture, engineering, home economics, etc.; adult education; research and graduate study; and student relations and welfare.

Dr. Arthur J. Klein, Chief of the Division of High Education of the United States Bureau of Education, is the Director of the Land Grant College Survey.

Advisory committees have been appointed by the Commissioner of Education upon the recommendation of the national technical groups concerned. The advisory committee on Engineering includes: A. W. Berresford, President, American Engineering Council and L. W. Wallace, Executive Secretary, American Engineering Council to represent the engineering societies; and Deans, R. A. Seaton, Anson Marston, and G. W. Bissell, as the representatives of the Engineering Division of the Association of Land Grant Colleges and Universities.

The author of this paper was appointed a member of the U. S. Bureau's Survey Staff, with the title Consulting Expert, to give general direction to the nature of the inquiry on engineering. One of my functions in this connection is to insure in so far as possible, that the Land-Grant College Survey did not unnecessarily duplicate the S. P. E. E. study of engineering education. On the basis of my general suggestion, Dr. W. C. John of the Division of Higher Education and Mr. Maris Proffitt, Specialist in Industrial Education both of the U. S. Bureau of Education Staff, are preparing a detailed draft of the schedule on engineering. This draft will be submitted to me for review for the purpose of preventing duplication with the S. P. E. E. Study, and in order that it may be most useful to the engineering schools of land-grant institutions. After consideration by me the draft will be submitted to the Engineering Advisory Committee for the Land-Grant College Survey before it is sent to the institutions concerned. Every effort is being made to secure for the engineering portion of the Survey the advice of those immediately concerned.

It is expected that the engineering portion of the Survey will be helpful in clarifying the functions, services, and responsibilities of land-grant institutions through their engi-

neering schools or divisions. It is also hoped that the data secured from this Survey will indicate what the engineering colleges of land-grant institutions have contributed to the industrial, economic and social progress of the United States of America through the training of experts, the creation of new engineering knowledge through research, and other services to the public through engineering extension.

AGRICULTURAL ENGINEERING *

BY J. B. DAVIDSON,

Professor and Head of Department of Agricultural Engineering,
Iowa State College

The aim of this paper is, first, to outline the scope and character of that branch of engineering education known as agricultural engineering, and second, to report the development and present status of agricultural engineering in the educational program of the country. As one having had a long term of service in agricultural engineering education, I hope to qualify for the first task and for the latter I will use data and information collected by the committee on Education of the American Society of Agricultural Engineers.

It is an avowed desire on the part of the writer to cultivate the sympathy and favorable interest upon the part of engineering educators. As is usually the case with a new development, the critical attitude displayed by those in recognized and established lines of work furnishes the need for careful and extended thought on the part of those responsible for the new proposals. No doubt this conservative attitude is very beneficial in heading off unsound developments but is often a real trial to the pioneers.

The two most common questions presented by those who would try the faith of the sponsors of agricultural engineering are first, what is agricultural engineering, and second, is agricultural engineering really engineering? In order to discuss these questions it may be necessary to present a premise or two or establish a viewpoint from which to proceed. Could it be agreed in the beginning that agriculture is an industry committed with the production of food and raw materials used for food, shelter and clothing? Is not agriculture recognized as a primary industry of great importance because

* Presented at the 36th annual meeting of the Society, University of North Carolina, June 26–28, 1928.

it supplies a fundamental need of all persons? It must be an important industry, furthermore, because approximately one-fourth of those gainfully employed are in the industry. I am mindful of the fact that in agriculture, social problems are closely related to production, but I am not willing to admit that agriculture is solely a "mode of life." The responsibility of agriculture to society in general is the production of an adequate supply of agricultural products, of good quality, and at a reasonable cost. For the production of these commodities the proper number of people required to carry out the production needed are entitled to enjoy the same standards of living as those in other activities.

Agricultural engineering has been defined as that branch of engineering concerned with special applications of engineering to agriculture. Its organization is more similar to electrical engineering, which is likewise related to an industry, than civil and mechanical engineering, direct divisions of the profession. If it can be proved that engineering fills an important rôle in agricultural production, then the importance of agricultural engineering should be established.

An accepted definition of engineering is: "the art and science of organizing and directing men and utilizing the forces and materials of nature for the benefit of mankind." In common terms the work of the engineers deals with three important factors of production, viz.: labor—"the organization and direction of men;" power—"the forces of nature;" and materials—"the materials of nature." If it can be established that labor, power, and materials are important in agricultural production, agricultural engineering should be fully established as an important branch of the profession.

As suggested previously, about one fourth of the labor of the country is employed in agriculture. There is no reason why the efficiency of agricultural labor should not be improved by engineering methods like labor in other industries. From twenty to eighty per cent of the cost of production of agricultural crops is charged to labor indicating in another way the importance of labor.

As to power the last Census reveals that the primary power

used in agriculture, 40 million horse power, exceeds by one third the primary power used in manufacture. The energy consumed in horse power hours, however, is less than in manufactures because of the low load factor. Agriculture, however, according to a survey recently made by the Division of Agricultural Engineering, U. S. Department of Agriculture, and reported in Bulletin 1348 is approximately 16 billion horse power hours. It is to be recognized that much of the power used in agriculture is animal power but the application of animal power has been particularly neglected by engineers. Professor Thurston of Cornell University seems to be about the only engineer of eminence to have given the animal motor attention.

The production of agricultural products involves many varied operations, many of which are quite far removed from the mechanical operations which generally prevail in the factory. Nevertheless, it is interesting to study the influence of the use of power on the value of crops produced by the agricultural worker. Such a study setting forth this relation by states and countries has been reported in the bulletin just mentioned. This report indicated a direct relation between the power used and the value of crops produced. The following table indicates this relationship:

TABLE I*

Country or state	Primary power per agricultural worker	Value of crops Produced annually
Italy	.19	$ 45.00
France	.37	90.00
Germany	.55	119.00
United Kingdom	.88	126.00
Alabama	.81	112.00
New York	1.69	250.00
Indiana	2.46	365.00
Iowa	3.86	595.00
Nebraska	4.71	910.00

* Bul 1348—U. S. Dept. of Agr., p. 17.

Many of the farm surveys indicate a direct relation between the investment in machinery and the farmer's income.

Under-equipped farms cannot compete with farms properly equipped, with mechanical equipment which has but one function, that of substituting power for manual labor.

Farm structures offer another opportunity to apply engineering to agriculture. In the production of livestock and livestock products, mechanical equipment and housing conditions are important factors. The efficiency of labor depends directly upon the convenience of arrangement and the character of the equipment. Livestock cannot be expected to do well unless housed in comfortable and sanitary quarters. A considerable proportion of the total building construction of the country is on the farms. The Census reveals that 14.7 per cent of the fixed capital invested in agriculture is represented by farm buildings being exceeded only by the value of the land itself. The annual increase in the value of farm buildings from 1909 to 1919 was 516 million indicating an annual expenditure much larger.

It is not possible to compare by means of vital statistics the health conditions in rural and urban districts because they are not available for the former. There is much evidence, however, to indicate that notwithstanding the generally favorable conditions which prevail in the country conducive to good health and longevity, the health conditions are not as good in the country as in well regulated cities. If this be true, the problem of rural sanitation must be recognized as important not only from the medical and biological standpoint, but also from the engineering.

Large areas of farm land in the United States have been reclaimed by drainage irrigation and land clearing. It should be pointed out now that practically all of the increase in farm land in the future must come from reclamation. At present there are about 500 million acres of improved farm land in the United States to which it will be possible to add 130 million acres of land by reclamation where needed.

Many purely manufacturing processes cannot be separated from the farm and must be carried on in conjunction with the production of raw materials. Dairy manufacture and fruit packing are examples of such processes. It is now suggested

that with the more general distribution of electric power to farms, certain manufacturing processes may be carried out on the farm to better advantage than elsewhere.

That engineering has contributed much to the advancement of American agriculture all unbiased observers must agree. Farm labor has become less arduous and severe and rural life more pleasant and comfortable because of the contributions that engineering has made. Engineering more than any other factor has enabled the American farmer to compete with foreign competitors. A few years ago several German scientists visited this country and the outstanding feature of their report on American agriculture was the large production per worker.

The United States exports rice in increasing amount to China. Here we have the extreme in contrasts; rice production in China by hand labor at a low wage, fifteen cents a day, and rice production in California by machine methods with the highest priced agricultural labor in the country, or 50 to 60 cents an hour with "found." The Chinese laborer boards himself. Is it reasonable to believe that engineering will continue to contribute to the progress and development of agriculture?

The purpose of the foregoing discussion has been to set forth as well as I have been able the relation of engineering to agriculture. If I have been able to make it clear that engineering has an important place in agricultural production and rural life, the educational problems related to the engineering of agriculture should be of interest.

In reporting the present development of agricultural engineering education, I will use data collected by a committee of the American Society of Agricultural Engineers of which Professor Quincy C. Ayres of Iowa State College is chairman. I have quoted freely from the reports of this committee.

Most of the state agricultural colleges offer instruction in agricultural engineering. In 32 institutions departments are organized to give instruction in the subject. Of these departments 28 are designated department of "agricultural engineering," two "rural engineering," and two "farm me-

chanics." In several other institutions instruction is offered but a separate department has not been established. Twenty-four of the departments are administered by the dean of agriculture, one by the dean of engineering, and seven are under the joint direction of the deans of agriculture and engineering.

The main function of these departments is to give instruction to students whose chief interest lies in various fields of specialized agriculture, home economics, or vocational education. These studies are often referred to as service courses. That these studies are engineering is just as reasonable as the chemistry taught to engineering is chemistry. These students do not expect to become engineers, neither do engineers expect to become chemists.

Ten departments of agricultural engineering in the United States and two in Canada offer four year courses leading to the degree Bachelor of Science in Agricultural Engineering.

Nineteen departments have staff members engaged in extension work on a full time basis and ten devote part time attention to this work.

Ten have full time employees engaged in agricultural engineering research and eleven others devote part time to projects of this nature.

In addition to the specific functions mentioned, all the departments carry on a large amount of general service work, including heavy correspondence with farmers of their representatives, the preparation of plans and construction advice, and the conduct of numerous demonstrations and short courses for farmers and their families.

Enrollment

As nearly as could be ascertained, the registration of agricultural students who were served by agricultural engineering departments during the session of 1924–5 was 5,000, and the total number in service courses since the first department was established (1904) is 78,000. These figures need to be modified somewhat to eliminate duplications, but it is believed they are not far from correct.

Professional Courses

In 1924–25 the total enrollment of agricultural engineering students in regular four-year professional courses was 192.

Perhaps a study of the positions filled by graduates of professional agricultural engineering courses will explain effectively the field and opportunity for the agricultural engineer. This table furnishes the results of such a study.

The miscellaneous column includes those graduates who have engaged in highway and municipal engineering, banking, merchandising and in the most recent and promising development in the rural electrification field. With the exception of the last named occupation, most of these are more or less unrelated to agricultural engineering and the number of men who have gone into them (16.6 per cent) may be considered "strays." It is noted that the largest percentage of graduates in any one occupation is that of those engaged in education and research. A great many of these have become heads of new departments (17 from Iowa State College alone) and it is a normal development to expect during the early years of any profession.

Two other movements worthy of note are the rapid development in rural electrification (already mentioned) and the agreement recently consummated with farm implement manufacturers whereby a definite number of graduates each year will be absorbed into that industry.

Considerable data were collected bearing on the income of graduates. This was found to compare quite favorably with the income of other engineering graduates, being somewhat higher during the first few years on account of the comparative absence of competition.

A brief study into the character and content of the ten professional courses would no doubt be of interest. These four year courses offered by the various schools are very similar in character and are essentially engineering courses having the same foundation subjects found in any good engineering course. A comparison of these courses with requirements of all engineering curricula as set forth by the Board of Investigation and Coordination of the Society for the Promotion

ACTIVITIES OF AGRICULTURAL ENGINEERING GRADUATES, JANUARY, 1926

The employment of graduates in agricultural engineering is indicated in the table below:

Name of Institution	Kind of Activity							
	Number of Graduates	Deceased	Education and Research	Farm Equipment Industry	Farm Structures	Land Reclamation	Farming	Miscellaneous
A. & M. College of Texas	16	0	1	3		2		10
Oklahoma A. & M. College	2	0	2					
Va. Poly. Institute	13[1]	0	6	2	1		1	3
Kansas State Agri. College	28[2]	0	11	6	1	3	3	4
Univ. of Nebr.—A.E. Degree	42	0	13	8	2	2	11	7
Major in Farm Mech.B.S. in Ag.	54	1	18	7	0	0	20	8
Iowa State College	157	8	62	19	10	13	25	21
University of Missouri	4[3]	0	2	1	1			
University of Saskatchewan	6	0	3				3	
Totals	268	8	100	39	15	20	43	45
Percentage	100%	2.9%	37.2%	14.4%	5.5%	7.4%	16%	16.6%

[1] Does not include 12 grads.—1924–25.
[2] Includes 3 men with A.E. degree.
[3] Includes 1 man with B.S. in Agri. Degree.

of Engineering Education in the report of November 1926 shows that the four-year course, leading to the degree of Bachelor of Science in Agricultural Engineering, meets these requirements even better than engineering courses in general. It is necessary to introduce survey courses in agricultural science to put the student in touch with the engineering problems of the industry. Naturally some time must be spent in emphasizing agricultural engineering subjects. The content on an average of the ten four year courses in agricultural engineering offered by the institutions of the United States will be about as follows: science studies 12 per cent; general engineering 30 per cent; cultural and general subjects 11 per cent; agriculture 15 per cent, agricultural engineering subjects 25 per cent; and electives or optional 7 per cent.

It is difficult to understand why anyone might contend that the agricultural engineering curricula does not prepare the graduate more adequately for professional service in the field of agricultural engineering than those courses intended to direct students into other channels. The support of special curricula in agricultural engineering by those who have entered the field from older branches of engineering would seem to be sufficient evidence of the soundness of the plan of a special course.

The field for specially trained agricultural engineers is admittedly not large. It would, in the writer's judgment, be a serious mistake for a large number of institutions to train agricultural engineers and furnish an output of graduates much in excess of the demand.

Owing to the present organization of agriculture into small operating units the agricultural engineer must practice his profession in connection with some organization large enough to recognize and employ an engineer. Agricultural engineers are therefore generally employed by educational institutions, manufacturing concerns, commercial organizations, trade associations, land development organizations, etc. An interesting feature of this situation is that there is little demand for a mediocre engineer. Either a mechanic is wanted or an engineer with managerial and executive ability.

The stability and promise of the future of agricultural engineering may be indicated by the work and standing of the American Society of Agricultural Engineers. Organized in 1907 with 17 members, the society now has nearly 700 members, a larger proportion of whom attend the meetings of the society than any professional society of which I have knowledge. These members, recruited largely from the older branches of the profession, have faith in and enthusiasm for their work. They believe that they have a real opportunity to serve.

The agricultural engineers engaged in educational work are very appreciative of the recognition accorded by the appointment of a Special Committee No. 23 on Agricultural Engineering. We have found much of profit to us in the work of the S. P. E. E. We would like to have you feel that we have a real task to perform and we believe that we are doing our work as well as we know.

REPORT OF COMMITTEE ON INDUSTRIAL ENGINEERING*

Among engineers in the older branches of the profession there seems to be considerable doubt as to the need for a separate branch of the profession ordinarily known as Industrial Engineering. Since Industrial Engineering has been practiced under various names for some twenty years, it appears that a thorough canvass of the situation is justified to determine whether industry really requires a type of engineer with somewhat different training from that offered by the older branches.

It is quite evident that the administration of modern American industry requires more of the scientific engineering view-point. Almost all of the growth which has taken place in the leading industries in this country is directly traceable to the efforts of engineers in all lines. There is every reason to believe that opportunities for research and expansion in American industries will continue to exist for many years to come.

In view of the demands by industry for men with this view-point, we may well inquire where such a view-point is to be acquired. It is evident that Colleges of Business Administration cannot impart in its entirety the correct background. It is likewise evident that Colleges of Liberal Arts cannot fully meet the specifications. The Departments of Physics, Chemistry and Mathematics in such colleges may contribute a part of the training acquired, but can hardly be expected to make the applications necessary.

In the Colleges of Engineering it would seem that the standard engineering courses are inadequate as regards certain types of industrial work. Engineers in increasing numbers are entering the field of administration in industry and are using less and less of their training in specialized designed

* Presented at the 36th annual meeting of the Society, University of North Carolina, June 26–28, 1928.

courses. On page 60, bulletin No. 3 of the Board of Investigation and Coordination of the S. P. E. E., is given a chart showing the distribution of functions performed in industry. Under administrative and managerial we find a steady increase in the percentage of graduates engaged in primarily administrative work. As the length of time following graduation increases, we find a corresponding decrease in the primarily technical work over the same periods.

In view of the reasons just stated, it would seem that a fusion of standard Engineering courses and Economics or Business Administration would more nearly meet the demands of modern industry. This fusion cannot be accomplished through specialized courses in Colleges of Business Administration, nor can it be accomplished through appended courses in Economics for Engineers. In view of the rapidity with which Engineering graduates drift out of the purely technical work into the administrative, it would seem that Colleges in Engineering would be justified in doing two things:

1. Cut down the proportion of strictly technical and design courses in all standard branches of Engineering.

2. Introduce courses setting forth fundamental factors included under the following heads:

a. Industrial Statistical Method.
b. Industrial Relations.
c. Accounting.
d. Industrial Economics.
e. Management.

In many Colleges of Engineering offering training in Industrial Engineering, Commercial Engineering, Administrative Engineering, etc., the courses are built somewhat to comply with the suggested fusion just outlined. Where such is the case there would seem to be a justification for this branch of Engineering as a separate growth in the profession. There is, however, so divergent a set of opinions as to what should be included in such courses that it is felt that this Committee should continue its study of individual courses in an effort to reach a course acceptable to industry.

The Committee believes that the necessity does exist for a course in Industrial Engineering. It also believes that it should be the function of this committee to continue studies of individual curricula so as to include in a final report a sufficiently broad survey of the field to meet the needs of any constituent institution.

Committee No. 9, Industrial Engineering.

S. T. HART,
STEWART SCRIMSHAW,
GEORGE H. SHEPARD,
R. D. THOMSON,
C. W. BEESE,
SUMNER B. ELY,
JOHN W. HALLOCK, *Chairman.*

REPORT OF COMMITTEE NO. 12—ENGLISH, JUNE, 1928*

The Committee on English of the Society has directed its work during the last few years along several lines, all of which it has been hoped would be useful in stimulating the development of the teaching of English in the engineering colleges.

The publication in the JOURNAL from month to month of articles dealing with the place of English in the engineering curriculum and with the practical problems involved in correlating English with other branches of instruction has served to bring teachers of English and teachers of other subjects into closer cooperation in dealing with this important matter.

The conferences on English which have been held in connection with the annual meeting of the Society for the past seven years have made clear several points of agreement which apparently now need no further discussion. Among these matters of agreement the following are especially to be noted: the important place of English in the training of engineering students and as part of their educational experience; the growing appreciation that the tool value of English is not all, that its humanistic value is of equal, if not of greater importance as justifying its place in the curriculum; the deepening sense of the common responsibility of all members of the faculty in correcting the student's use of English and in developing in the student a real taste and enthusiasm for good books. These, of course, are not to be regarded as achievements but as ideals which, through the discussions held at these conferences, have come to be clearly understood and generally accepted.

Last year the very practical problem of securing teachers of a type fitted to do this work in the most effective manner was brought under discussion at the joint meeting of the

* Presented at the 36th annual meeting of the Society, University of North Carolina, June 26–28, 1928.

teachers of English and the Deans. It was pointed out that teachers of English outside the engineering colleges are not especially sympathetic nor appreciative of the opportunities afforded by this work, that they are skeptical of the professed interest of the engineering colleges in the teaching of English and that they fear to be ostracized by their associates in the Arts College, if they commit themselves to a phase of education which is so practical in its objectives; that they fear to jeopardize their chances for professional advance and to limit themselves in their personal development by teaching work which appears to be disciplinary in its character. It was agreed that if teachers are to be recruited for this important work, they must be shown that there is here an inspiring opportunity for educational service, that their students are likely to be even more serious and earnest in their work than in less homogeneous groups, that they must be given favorable working conditions and that they must be assured places of dignity and equality on the engineering faculty.

This year the ideal of English as a developmental experience for the student rather than as a mere formal course or series of courses was discussed by the teachers present at the conference.

Perhaps the most important results have come from the informal conferences which have not been a part of the regular program, but which have given opportunity for the very intimate discussion of the problems which the teachers of English themselves have encountered in their work. Often the Committee on English has been in almost continuous session during the days of meeting.

Perhaps the Society generally has not known that the Committee has for the past four years been engaged in a quiet but persistent investigation of the status of English teaching in the engineering schools. This research has necessarily proceeded somewhat slowly since no funds were available and the Committee, both individually and collectively, had only limited time at their disposal. It may be of interest to the

Society to know the general scope of this investigation and the lines along which it has been conducted.

The program of investigation which was laid out four years ago covered the following studies:

1. Classification of freshmen.
2. Supplementary work.
3. Courses in English Composition.
4. Courses in English literature.
5. Combination courses.
6. Plans for checking students' careless habits of expression.
7. Plans for securing cooperation of the entire Faculty.
8. Senior English courses.

Professor Birk's report on "The Study of Inter-Departmental Cooperation to Promote Habitual Use of Correct English" was published in full in the JOURNAL OF ENGINEERING EDUCATION for December, 1925. In this report he pointed out that over 91 per cent of the replies to the questionnaire regarded some plan of cooperation between the teachers of English and the teachers of technical subjects in the development of student habits of expression as highly desirable; 70 per cent regarded some such plan as fundamental, and only 13 per cent questioned its practicability. Professor Birk in his report made a special study of the cooperative plan used at the University of Cincinnati, a plan which has been largely copied in whole or in part by a number of other schools.

At the conference a year ago Miss Harbarger presented a report of her very complete study of the beginning course in English composition. Because of the large amount of material which the Board of Investigation has had to publish this year Miss Harbarger's report has not yet appeared. In this report she has shown that there exists no great uniformity in the administration of these courses. In many schools the engineers are still enrolled in the freshman English courses in the Arts College. In an increasing number they are taught in segregated sections and in both cases there seems to be an increasing recognition of the possibility of motivating their work through an appeal to their professional interests. How-

ever great the diversity of usage in the administration of this work there is no question that there is a definite recognition of the tool value of English for the engineer. This tool value has in the past been perhaps even over-emphasized and is now being somewhat balanced by a realization of the almost equal importance of developing in the engineering student an appreciation of the best in literature. It is evident from Miss Harbarger's report that there is no need for alarm as to the likelihood of the professional aims of engineering students being overstressed or the broadening aspects ignored in the first year English. Standardization of this work is not indeed to be desired if only all teachers can be inspired to employ a method of teaching which will provide a means for building up the student's interest in gaining a command of English and an appreciation of literature. The emphasis in her report is very strongly upon the supreme importance of teachers with right ideals.

The Chairman of the Committee has, in the meantime, been making studies of the combination courses and of the development of elective courses in the appreciation of literature by which the students experience with English may be extended beyond the freshman year up through the later years of his course. His report on these studies will be published later.

The Committee in its original plan expected to complete the program of investigation and to present its complete report to the Society one year from this time. It still seems likely that this work can be completed by that time and the report presented.

There is one further aspect of the work of this Committee which is of some importance. Through correspondence and through the effect of the conferences the Committee has hoped to inspire a professional pride and group consciousness among those teachers who have committed themselves to the teaching of English in the engineering college. The group is still very limited and the work is still largely experimental, but with each year there has apparently developed a clearer vision of the objectives and aims which must inspire this work and

a more earnest desire on the part of the English teachers to cooperate with the engineering colleges.

Those of us who have been pioneering in this work for the past twenty years are glad to welcome recruits who, like ourselves, are willing to commit themselves to the cause of engineering education and make their contribution through the teaching of English.

Respectfully submitted,

J. RALEIGH NELSON, *Chairman*,
W. O. BIRK,
H. M. ELLIS,
SADA A. HARBARGER,
H. G. PEARSON,
H. C. RICHARDSON.

REPORT OF COMMITTEE NO. 15—CIVIL ENGINEERING, JUNE, 1028 *

The committee has chosen as a two-year study *"The Coordination of Surveying as Taught in Colleges and as Used in Practice."*

A set of questions was prepared by the committee and was sent informally to one Highway Commission and to six railroads, all of which have replied. The replies were so encouraging that a general request is being made to a large number of railroads, highway commissions and other organizations and individuals.

The greater part of the inquiries was sent out within the past week. Others will be sent as occasion demands. The replies will be analyzed in time for a final report at the next Annual Meeting.

A copy of the questions and of the individual letter which accompanied them is attached.

Respectfully submitted,

F. H. CONSTANT,
F. O. DUFOUR,
HORACE JUDD,
J. R. LAPHAM,
A. H. FULLER, *Chairman.*

THE COORDINATION OF SURVEYING AS TAUGHT IN COLLEGES AND AS USED IN PRACTICE

A request for data from the Committee of Civil Engineering of the Society for the Promotion of Engineering Education.

F. H. Constant, Princeton University, Princeton, N. J.,
F. O. Dufour, Lafayette Colege, Easton, Pa.,
Horace Judd, Ohio State Univ., Columbus, Ohio.,
J. R. Lapham, George Washington Univ., Washington, D. C.,
A. H. Fuller, Chairman, Iowa State Colege, Ames, Iowa.

* Presented at the 36th annual meeting of the Society, University of North Carolina, June 26–28, 1928.

The Committee asks your cooperation in an attempt to reach a better understanding than now exists between the college and the employers of college graduates in regard to the emphasis which should be given in college to surveying.

The motive back of the inquiry is to see what correlation exists or may exist between the preparation the colleges are giving or may give and the needs and requirements of the organizations into which the college men go for their first outside experience.

The benefit of your experience and your judgment would be helpful in proportion as you considered the ultimate value of the graduate in your organization as well as his initial adaptability. Further training in surveying would necessarily be given at the expense of more complete training in advanced engineering subjects, in economics, or in other subjects which would contribute to a broader education.

We would greatly appreciate your assistance in consideration of this problem whether it was given as a discussion or as replies to the following questions.

1. Do college graduates work to advantage in your organization

(*a*) during the first few weeks?
(*b*) after several years?

2. Would they be of greater value to you if they had more training in surveying and less training in advanced technical and in general subjects?

5. If so, what subjects do you believe should be given greater emphasis?

(*a*) Advanced technical (railroads, highways, structural, sanitary, etc.).
(*b*) General (economics, psychology, history, English, foreign language, etc.).

4. Would they be of greater value to you if they had less training in surveying and more in advanced technical and general subjects?

5. If so, what subjects do you believe should be given greater emphasis?

(*a*) Advanced technical (railroads, highways, structural, sanitary, etc.).
(*b*) General (economics, psychology, history, English, foreign language, etc.).

6. Would you consider it practical to modify your present standards in breaking in college graduates to conform to either more or less college training in the theory or in the technique of surveying.

7. One reason for emphasizing the theory and the technique of surveying is that it is the first opportunity in a college course for the application of mathematics and drawing to an engineering subject. It is

possible that these applications will provide desirable motivation and will create a background for better understanding of theory later in the course and therefore contribute economically to scholastic development.

Do you believe that this viewpoint is of sufficient importance to emphasize surveying in college beyond the point which is necessary for efficient work in surveying in your organization?

8. Will you check on the following list of phases of surveying the degree of proficiency which you consider the most economical for a college graduate in order to work and to develop to the best advantage in your organization. In checking, will you keep in mind questions 2, 4, 6 and 7.

Phases of Surveying	*None*	*Little*	*Medium*	*Much*
Chaining and rodding.				
Use of level and transit.				
Adjustments of level and transit.				
Stadia work.				
Plane table work.				
Sextant work.				
Astronomical work.				
a. Meridian from stars.				
b. Meridian from sun.				
c. Latitude.				
d. Longitude.				
e. Time.				
Note keeping.				
Plotting and mapping.				
Computations of area.				
Cross section work.				
Circular curves.				
Laying grade lines.				
Computation of earthwork.				
Emphasis on the proper degree of precision.				
Care of equipment.				

9. Have you been able to note any marked differences between men whose surveying had all been on a college campus and those who attended a "summer camp"?

If so, will you indicate the various distinctions you have noted, using another sheet or the back of this sheet if you need more space than is available here.

The Committee will greatly appreciate your replies and will acknowledge them. Will you mail them to:

A. H. Fuller,
Iowa State College,
Ames, Iowa.

Replies made by:
Name .....
Position .....
Organization .....

Date .....
Address .....
.....

Dear Sir: You are doubtless familiar with the extensive study of engineering education which is being made through the Society for the Promotion of Engineering Education. Committee No. 15, of which I am chairman, has been assigned a small portion of this task, as indicated by the enclosed questionnaire.

If you would make, or secure from other members of your organization, a reply which would be representative of your experience and your judgment, you would give both assistance and encouragement in this study; you would therefore contribute to a more helpful understanding between the colleges and the employers of college men.

The committee trusts you will be willing to make this contribution.

Sincerely yours,

A. H. FULLER,
Chairman.

REPORT OF COMMITTEE NO. 25—RELATION OF ENGINEERING COLLEGES WITH RAILROADS—JUNE 1928 *

Your committee appointed a year ago has pursued the time-honored custom of attempting to ascertain the facts pertinent to its problem before proceding to conclusions and recommendations.

Two luncheon conferences have been held with representatives of the American Railway Engineering Association Committee No. 24—Relations of Colleges and Railroads, the Committee on Public Relations of the Eastern Presidents' Conference, the Executive Committee of the Railway Division of the American Society of Mechanical Engineers, and the Sub-Committee of this Division on Professional Service, and several individuals prominently identified with education and training for railroad service.

The first of these conferences was in New York City on December 6, 1927, at the time of the Annual Meeting of the A. S. M. E., the second in Pittsburgh, May 15, 1928, during the Spring Meeting of the A. S. M. E. The Pittsburgh conference was unanimously in favor of continuing the discussion at the Annual Meeting of the A. S. M. E. in December 1928. In brief, the discussions developed much significant data, experience and opinion with reference to the situation and its implications from the viewpoints of:

(*A*) The schools,
(*B*) The railroads,
(*C*) The graduate employee.

The Schools observe with concern the apparent lack of activity or even interest on the part of some railroads in special efforts for the procurement of technically trained men

* Presented at the 36th annual meeting of the Society, University of North Carolina, June 26–28, 1928.

having a personal interest in or aptitude for railroad work, or in systems of training, or of progressive advancement of such employees after they enter the railroad service. They believe that this results in many capable, high grade men being diverted from a railroad career to the detriment of the railroads.

The schools are now adjusted to well-organized systems of procurement on the part of industry. This is missing from most railroads, and is believed to result in unfavorable comparisons and misjudgments.

The colleges tend to emphasize intellectual and technical qualities and take for granted the personal qualities. The personal qualities loom very large in all but the strictly technical and routine activities of the railroad. Advancement depends largely upon these qualities, notably in the case of the higher executive positions. The schools have a responsibility here to the railroads and to the students. They should interpret to their students the attitude of the railroads in the light of all these facts, and with regard to their requirements, which differ materially from most industries.

Technical courses and particularly railway engineering courses in engineering schools tend to feed men into the Engineering, Maintenance of Way, Motive Power or Mechanical Departments of railroads. The railroads apparently look to the schools for men who are well educated. They prefer training in fundamental principles rather than in special railroad technique.

The Railroads' position is well expressed in a recently published report * of a nation-wide survey of current methods in transportation, as follows:

"Practically every railroad organization now relies upon its ordinary apprentice system of training for the development of its mechanical personnel. An interesting experiment during the past few decades has been the attempt on the part of a few railroads to enlist technical engineering graduates in this department by the establishment of so-called special apprentice systems. However, as the positions requiring

* "Transportation, A Survey, etc." Topping & Dempsey, 1926, p. 28–29.

engineering education are not very numerous, the railroads can, through this channel, absorb comparatively few engineering graduates.

"Varying degrees of success have been recorded. In some cases, those in charge are enthusiastic over the possibilities of the system, while from others come disheartening reports of the college graduate in the railroad business."

In general, the emphasis is placed upon personality, physique, ability to work with and to direct others, capacity for hard work and the "love of the game" rather than scholarly attainment, technical skill, or intellectual ability. The salaries and opportunity for advancement are believed by many to be as good as the conditions on the railroads permit. Apparently, they are sufficient to attract the quantity and quality of men needed. The quality of training on several roads is distinctly improving, the level of acceptability is being steadily forced up.

The railroads, however, are no longer expanding industries. Hence, the demand for technically trained men is correspondingly less. The supply companies must have brains and vision focussed intensively on the detailed technical problems of the railroads they serve. They carry the burden of much of the pioneer technical development work formerly handled by the railroads themselves. Traffic and executive planning are not particularly well provided for by men trained strictly along engineering lines.

Opportunities on railroads are believed to be as good as in industry for a limited number of men with the right personal qualities. The railroads appear to be able to use the broadly trained man with good personal qualifications to better advantage than the highly trained technical man who lacks the personal qualities particularly advantageous in railroad service. The attitude of the railroads on publicity and the education of the general public railroad-wise has decidedly changed during the last five years. There are more college men in executive positions on railroads now than ever before, and they are decidedly on the increase.

The Graduate Employee on the railroad, unless thoroughly in love with the "game" and fitted for it, both temperamen-

tally and physically, is likely to become discouraged with what seems to him inadequate pay, slow advancement, and, in some cases, what he interprets (perhaps mistakenly) as indifference. Even on roads having well organized and effectively administered training courses, the process of orientation and assimilation does not always progress without maladjustments and dissatisfaction. The graduate apprentice is doubtless largely responsible, individually.

* "Despite the undoubtedly strong training value of the course the results were disappointing, both to the management and presumably to the students themselves. One main difficulty on the part of the student system arises from the dislike on the part of the regular employees for anything which savors of class distinction. This attitude and the inexperience of the student himself in handling men put him at considerable disadvantage on appointment to junior official rank, and in this way his progress was retarded. It has been said also that a large factor in the failure in this particular was skepticism on the part of non-college executives. Students are often considered by the practical men to have only a smattering of business and they are too often, perhaps rightly, said to lack judgment."

The failures and the dissatisfied are likely to attract more attention than the successes, but the increasingly large number of college trained men in executive positions indicates decided progress.

To summarize the situation briefly:

The schools believe they should make better provision for the needs of the railroads, but are not sure of the direction in which, or the channels through which they can best accomplish improvement.

The railroads view the problem largely as an administrative function to be worked out by each individual road and with each individual employee on the merits of the particular case. They appear satisfied on the whole with the results of existing methods. They show no evidence of a desire for concerted action on the problem.

The graduate employees succeed and they fail; whether more or less than in industry generally is, perhaps, debatable. It does seem clear that the requirements are more severe, the

* "Transportation, A Survey, etc." Topping & Dempsey, 1926, p. 32.

progress slower, and on the whole the rewards less certain than in some other industries.

What then is the function of this committee? Further conference and discussion, unless directed toward specific ends, seems likely to revolve around the several major factors above mentioned without accomplishing very much.

The official heads of the railroads stand ready to consider and take appropriate action upon any program that the schools can submit which promises improvement in the conditions discussed. This was very clearly brought out in an informal conference with the presidents of several of the leading Eastern railroads in New York, December, 1926.

Two definite suggestions have been made.

(1) To arrange, through the proper channels, for the presence at the next meeting of the Committee of certain responsible railroad officials prepared to speak with authority and, where advisable, to act on certain definite questions of fact and procedure to be placed before them.

(2) To set up some definite channels of communication between representative railroad group organizations and the colleges which will facilitate the flow of information and of cooperative effort in both directions.

With reference to the latter, it should be observed that the Committee on Public Relations of the Eastern Presidents' Conference already constitutes one such channel available to educational institutions and the public generally for information, lectures and assistance in making railroad contacts of all descriptions, on application to Mr. J. M. Fitzgerald, Assistant to the Chairman, 143 Liberty Street, New York City.

Respectfully submitted,

M. S. KETCHUM,
ANSON MARSTON,
C. H. MITCHELL,
A. A. POTTER,
H. E. RIGGS,
G. F. SWAIN,
F. E. TURNEAURE,
S. W. DUDLEY, *Chairman.*

Appendix

Questions for Discussion

With a view to clarifying the relationship that should exist between steam railroad companies and universities, colleges and technical schools, in respect to their graduates entering railroad service as a vocation, the following is submitted:

Expanding industries canvass the colleges to enlist the services of promising men.

The college man in these industries must learn by experience to cope with the tasks confronting him.

Honesty, perservance, willingness to do dirty work, tact and ability to get along with men are important in industry as well as on the railroads.

It is appreciated that railroads are not expanding and their need for engineering graduates will be limited.

In view of all the facts, is a mutually serviceable cooperation between schools and railroads feasible and desirable?

For the purpose of obtaining the convictions of railroad executives in the premises, and with no intention of implying any adverse criticism upon the present railroad policy, we desire to know whether responsible executives having oversight of this field might be approriately asked to respond to the concrete inquiries listed below:

1. Is it your view that entrance upon railroading as a vocation and success therein must be of necessity, in general, a matter of individual initiative; and that this situation is one which cannot be essentially altered or bettered by instituting cooperative efforts between railroads and the schools specially directed towards the preparation or selection of college men for railroading as an occupation?

2. Is it your view that only in certain distinct fields or departments, such as construction and repair work in shops, in maintenance of way work, handling of stores, traffic work, train operation, etc., is the plan of special apprenticeship or special training of apprentices likely to make an apprentice system (with the systematized selection of candidates for such training) really worth while to the company?

If worth while, should such apprenticeship or special training for each concrete field be a continuous and systematic arrangement, or should it be resorted to for such periods only as seem to make the results thereof worth while?

3. Is it your view that a desirable course of training for future railroad officials of executive rank should include a preliminary experience in various fields, such as station service, yard service, train service (as brakeman and conductor), in operation and maintenance under the division engineer with the master mechanic, the storekeeper, the trainmaster, the accounting and auditing bureaus, as well as in the field of railroad finance? Or is such an attempt to bridge a number of related fields too pretentious to yield results of substantial value?

REPORT OF COMMITTEE NO. 27—MECHANICS, JUNE 1928*

During the past year, your Committee on Mechanics has investigated current practice among its members upon several points in the teaching of mechanics. A questionnaire was circulated to ascertain how the percentages of quiz, test and examination questions were divided among the following:

(*a*) Definitions.
(*b*) Discussion.
(*c*) Derivation of formulæ.
(*d*) Solution of problems.

Replies were received from six members of the committee, with the following results:

(*a*) Definitions. Used only by three, percentages varying from 2 to 25, average 5.

(*b*) Discussion. Used by two, percentages 3 and 5.

(*c*) Derivation of formulæ. Used by five, percentages varying from 5 to 45, average 18.

(*d*) Solution of problems. Used by all, percentages varying from 50 to 100, average 75.

It is seen from these results that in tests and examinations in Mechanics, the solution of problems is considered to be of paramount importance, the derivation of formulæ of much less importance, and that definitions and discussion are considered to be of very minor importance.

Another question investigated was the use of sets of review questions at the end of the semester's work. In this case, the committee was evenly divided, three using review questions and three not using them. Those who use them feel that the list of review questions is the best means of enabling the student to clarify and coordinate the various isolated facts acquired during the semester. Those who do not use them

* Presented at the 36th annual meeting of the Society, University of North Carolina, June 26–28, 1928.

feel that each new principle and method should be mastered thoroughly as it is taken up, and that with no time allotted for review, lessons may be shorter and will be studied more thoroughly and effectively. The committee will welcome further discussion on this subject by anyone who may be interested.

A third question investigated was the use of the "true-false" type of test or examination in mechanics. The members of the committee were unanimously of the opinion that this type of examination had no place at all in such a subject as mechanics, that the student's knowledge of the principles of mechanics and his ability to use them can be tested so much more easily and effectively by properly prepared problems, that it would be folly to attempt to use the "true-false" examination. As indicated above, further discussion will be appreciated, especially from those who may differ with the committee.

Respectfully submitted,

G. P. BOOMSLITER,
J. E. BOYD,
S. G. GEORGE,
C. C. MORE,
C. E. PAUL,
S. M. WOODWARD,
A. P. POORMAN, *Chairman.*

MEMBERS

Last year there were over sixty thousand engineering students in American Engineering Schools. Not less than six thousand teachers were required for their instruction.

Our society has a total membership of two thousand—a short third of the normal membership from teachers alone. The entire field of engineering and industry is represented by only two or three hundred members. That should be increased many times.

The activities and accomplishments of this Society during the past five years are truly gratifying. Undoubtedly they will have a very far reaching effect on educational trends, and so on the trend of civilization.

The time is now ripe to strengthen the membership and greatly extend the influence of the society and the scope of its work.

Securing new members must be by the individual members; the membership committee can not do it. We depend entirely on you.

Later we will ask individuals for specific assistance—now we ask that each member bring in his friend.

The membership committee is now composed of

G. W. Bissell, Michigan State College
F. C. Caldwell, Ohio State University
W. N. Gladson, University of Arkansas
E. R. Maurer, University of Wisconsin
D. A. Murray, McGill University
H. S. Rogers, Oregon Agricultural College
G. W. Munro, Purdue University, *Chairman*

COLLEGE NOTES

The Engineering faculty of the **University of Detroit** has been increased by ten new members. Associate Professor L. S. Johnston, formerly of Pennsylvania State College, is to have charge of the Department of Mathematics. Mr. R. W. Tapy has been appointed instructor in Electrical Engineering, Mr. E. Miller instructor in mathematics, Mr. J. H. Higgins assistant professor of Aeronautical Engineering, Mr. L. R. Blakeslee instructor in Architectural Engineering, Mr. D. M. Bigge instructor in Physics, Mr. Hawkes instructor in Chemistry, Mr. Ralph Stoody laboratory assistant, and Mr. C. L. Altenburger instructor in Metallurgy. Mr. H. M. Keal, formerly of Cass Technical High School, has been made coordinator in place of Mr. J. J. Caton who resigned in June, and Mr. W. S. Reilly, a graduate of the University of Detroit, has been apointed as assistant coordinator.

The new additions to the faculty have been made necessary by the increased attendance. There has been an increase of about 30 per cent in the freshman class, which now numbers 460. The other classes have had a total increase of 90 students who have transferred from other colleges. The total attendance is now 1070 an increase of 270 over the year 1927–1928. The aeronautical department, the largest in the Engineering College, has an enrollment of 300 students of which 150 are freshmen.

The coordination periods have been changed from two weeks to four and the school year from ten and one half months to eleven. A canvass of all employers of engineering students was made last year and without exception all employers favored the four week period. It is also the opinion of the faculty that the four week school period will be more effective than the two week period. Thirty months of school work are now required for graduation. This compares favorably with the regular four years course of thirty five months.

University of Maine.—College of Technology faculty changes include resignations of Joseph F. Kolouch and Harold B. Friedman, instructors in Chemistry, and George E. Spencer, instructor in Civil Engineering, and appointments of Robert N. Pollock, M.S., Lawrence L. Osborn, A.M., and David H. Stevens, B.S.

The Crosby Laboratory of Mechanical Engineering, which houses hydraulic, gas and steam engine and materials testing laboratories, was ready for occupancy this fall. The building is practically complete, and the hydraulic laboratory is especially satisfactory.

The new so-called one-point rule, adopted by the engineering college late last year, is now effective. The University grading system employs the letters grades; A indicating passed with high honors; B, passed with honors; C, passed satisfactorily; D, passed unsatisfactorily; E, conditioned; F, failed. The equivalent in percentages is as follows: A—97½ per cent or 95–100; B—90 per cent or 85–95; C—80 per cent of 75–85; D—72½ per cent or 70–75. In the averaging of grades A is assigned a value of 4.0; B, 3.0; C, 2.0; D, 1.0; E. O; F, double O. The new ruling drops from the College of Technology any student who fails to make an average grade of as much as one point (1.0) at the end of the first semester of his freshman year. This rule was adopted after an intensive study of the college records of engineering students entering the University in 1922 and 1923 had been made by Professor W. S. Evans. The study showed that of the students receiving an average of one point or less during their first college semester, not a single individual succeeded in finishing the regular college course in four years, and that only one per cent succeeded in completing the work in five years or more.

College of Technology faculty members taking graduate or special work are E. J. Felker, Alvin Sloane, T. A. Sparrow, D. H. Stevens, H. D. Watson and A. O. Willey.

Economics and Human Geography, a course designed for mill and factory foremen and overseers, is being given by Bates, Bowdoin and Colby Colleges and the University of

Maine this fall. This is the initial step in a joint movement of the Associated Industries of Maine and Maine colleges to have special courses made available for industrial workers. The course will be given by some of the institutions at their college campus; by others elsewhere when this arrangement locates the class more centrally for those in that section of the state who may be expected to enroll for it. Professor W. W. Chadbourne will conduct the University of Maine course Thursday evenings at the University campus.

The Pennsylvania State College.—The new engineering building now under construction will provide modern offices, a large hydraulic laboratory in the basement, and a third floor designed especially for instruction in architecture, architectural and civil engineering design.

SECTIONS AND BRANCHES

The **Purdue branch** of the S. P. E. E. held its first meeting for the school year, October 12, 1928. President O. A. Greiner presided.

The subject for discussion was "Student Mortality in the Freshman and Sophomore Classes in Engineering."

The discussion was led by: Professor Stone, Registrar; Professor Erickson, Civil Engineering; Professor Ludy, Mechanical Engineering; Professor Test, Chemistry; Professor Cattell, Modern Languages; Professor Marshall, Mathematics.

The meeting was attended by 36 members.

There was also an election of officers. Prof. W. Aitkenhead of the Agricultural Engineering Department was elected President, and Mr. R. W. Lindley of the Practical Mechanics Department was elected Secretary.

R. E. WENDT,
Secretary.